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ABSTRACT

This document consists of data which highlight trends in all sectors relevant to environmental policy. These data are presented in the form of charts and maps contained in 13 sections under the following headings: people and the land; critical areas (wetlands, wild areas, parks, historic places, and risk zones); human settlements; transportation; material use and toxic waste; toxic substances (pesticides, industrial chemicals, metals, and radiation); cropland, forests, and rangeland; wildlife; energy; water resources; water quality (rivers and streams, lakes, and oceans); air quality; and the biosphere (population, land, wildlife, oceans, and atmosphere). Each chart or map is accompanied by a brief discussion highlighting the changes noted. Among the findings reported are: (1) a reduction in total suspended particulates and sulfur dioxide concentrations in urban air; (2) a continual reduction in the extent of natural land areas in the United States; (3) a dramatic change in the patterns of land use in the U.S. (such as human settlements locating in areas once avoided because they were too hot or cold); and (4) changes in the condition of the land due to natural and/or human factors. (JN)

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Environmental Trends

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Environmental Trends

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Washington, D.C.

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U.S. Department of the Interior

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July 1981

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While the Council acknowledges the help and support of many, it is solely responsible for the final selection, organization, and presentation of the data.

Contents

Introduction, *iv*

1 **People and the land,** *1*

2 **Critical areas,** *15*
  - Wetlands, *16*
  - Wild areas, *22*
  - Parks, *28*
  - Historic places, *36*
  - Risk zones, *38*

3 **Human settlements,** *45*

4 **Transportation,** *61*

5 **Material use and solid waste,** *75*

6 **Toxic substances,** *89*
  - Pesticides, *92*
  - Industrial chemicals, *100*
  - Metals, *106*
  - Radiation, *110*

7 **Cropland, forests, and rangeland,** *117*

8 **Wildlife,** *147*

9 **Energy,** *175*

10 **Water resources,** *209*

11 **Water quality,** *237*
  - Rivers and streams, *240*
  - Lakes, *262*
  - Oceans, *266*

12 **Air quality,** *271*

13 **Biosphere,** *295*
  - Population, *296*
  - Land, *304*
  - Wildlife, *318*
  - Oceans, *324*
  - Atmosphere, *330*

List of illustrations, *335*
Abbreviations, *340*
Conversions, *341*
Index, *343*

7

Introduction

Never again will there be a time in this country when Americans will not have to worry about and work hard to protect and improve our environment. To succeed in this task, we need to have and to share as much information as we can about what is happening in the many areas that make up the environment.

Environmental Trends is an effort toward that goal. It grew out of a realization that the Council wanted to make available more detailed information about environmental trends than could be included in the Council's annual report.

We initially considered putting together, in cooperation with other government agencies, a single index of environmental quality, an environmental GNP. We soon found that no single measure and no single index could tell us in a meaningful and valid way what the state of the environment was and whether or not it was improving.

What we did was organize the best data we could find to highlight trends in all sectors relevant to environmental policy. We selected data on air quality, water quality, radiation, toxic substances, land use and land conditions, parks, energy production and use, wildlife, solid waste, and many other areas.

The result is *Environmental Trends,* a collection of charts, maps, and text that record key changes in the environment and in related social conditions. *Environmental Trends* is intended to be a national briefing book that brings to life the many numbers and figures that measure environmental quality.

As work began on *Environmental Trends,* we realized that the range of topics to be covered was enormous. The number of statistical series was even larger. There were often many measures of change, or none. Many series did not measure quite what we were seeking—environmental changes associated with economic welfare, human health, recreational opportunity, aesthetic appreciation, and concern for ecological diversity and stability. It became our task to sort out the useful from the less useful and bring together the most important and informative data on environmental conditions and trends that could be found.

Five criteria were used to help judge the usefulness and adequacy of the statistics:

(1) Relevancy—that a statistical series provides data, wherever possible through direct measure, on a major environmental concern.

(2) Selectivity—that as few statistical series as possible be used to measure an environmental issue.

(3) Availability—that the statistical series be taken from data available in government agencies, private studies, or the literature of a given discipline.

(4) Statistical quality—that the data be checked by experts to ensure that they are reasonably valid measures of environmental conditions.

(5) Scope of coverage—that national data be used whenever possible, with breakdowns shown only when especially meaningful.

Improving environmental statistics is an evolutionary process. The agencies of government that collect and assemble environmental statistics are continually revising old series and developing new ones. We hope that *Environmental Trends* will be a useful tool in helping to develop a consensus on some of the most important statistical series for measuring environmental quality, by highlighting gaps in needed information and by strengthening the quality of existing series.

What, then, does the information in *Environmental Trends* tell us? Has the quality of the environment improved in recent years? In what areas is change most noticeable?

Perhaps the greatest progress has been made in controlling pollution. Concentrations of many pollutants are showing measurable decline.

Total suspended particulates and sulfur dioxide concentrations in urban air have been reduced.

Concentrations of suspended solids and biological oxygen demand are declining in many waterways.

There has been a marked reduction in the flow into the environment of DDT and other persistent organochlorine pesticides and of PCBs; of vinyl chloride and benzene; of asbestos; and of mercury, lead, and other heavy metals.

High concentrations of these and other chemicals in wildlife have declined, as shown by samples taken across the country.

While the number of sources of radiation are increasing, there has been no significant increase in the exposure of the general population.

But pollution problems remain. Although pollutant loads are being reduced, they are also being dispersed over long distances and deposited hundreds of miles away from the source.

Other forms of air and water pollution, such as photochemical oxidants and nitrogen oxides in urban air, respirable particulates in indoor atmospheres, and toxic substances in water, are proving to be more serious than once believed. For many of these problems, statistical trends are limited or are not available.

As the charts in *Environmental Trends* show, there has been a continual reduction in the extent of natural land areas in the United States.

Wetlands, virgin forest, native grassland, estuarine habitat, and other distinctive or unique habitat have been and continue to be lost. They have been lost mainly as a result of expanding and suburbanizing populations, expanded transportation systems, new settlements, dispersed industry, and increased demand for recreation sites. But the rate of decline in natural areas may be slowing.

In the past 10 years, many new national and state parks have been established, wilderness areas have been designated, wild and scenic rivers have been identified and maintained, and many other areas have been given some protection.

There has been a continual loss of biological diversity.

Although very few species of vertebrates have been officially declared extinct during the past 30 years, there has been a loss of diversity within ecosystems as a result of greater standardization of agricultural, forestry, and fishery practices and of other intensive uses of land and water. It appears that the long-term evolution that built complex, integral, stable ecosystems is being reversed.

Steps are being taken to slow this loss of diversity. Many more wildlife species are being given threatened or endangered status, and habitats critical to their survival are being protected. And, there is an increasing awareness that a much more systematic and comprehensive effort is needed to identify and protect fragile ecosystems. But the loss of diversity goes on.

Patterns of land use in the United States are changing dramatically.

Human settlements, recreation sites and second homes, industry, and energy exploration are being located in many areas that were once avoided because they were too hot (the Southwest), too cold (Alaska), without water (the Southwest), subject to high risks from natural hazards (such as steep mountain slopes and hurricane risk zones), or inaccessible (such as isolated coasts and the underwater continental shelf).

These trends are changing rural life and greatly influencing the extent, location, and quality of the remaining natural areas of the country.

The condition of land is also changing. Natural erosion, shifting vegetation, and wildlife expansion and decline continually change the condition of the land. But, apart from great storms and volcanic eruptions, nothing can change it as dramatically and as rapidly as people.

Soil erosion—once thought to be mostly under control—has become a serious problem in many parts of the Midwest.

Many arid and semiarid lands are rapidly becoming deserts as a result of overgrazing and overcultivation.

More than half the rangelands of the United States are not meeting their potential for growth of vegetation, usually as a result of overly intensive human use.

On a global scale, four life-sustaining biological systems—croplands, forests, grasslands, and fisheries, the sources of all food and many raw materials for industry—are being considerably burdened by increasing numbers of people and the accelerating demand for resources.

In particular, tropical moist forests, arid and semiarid lands, and some of the most productive croplands are being changed in use or in quality as people seek to feed themselves and provide a better life.

For decades, in fact, since the beginning of this Nation, Americans have believed that the quality of the environment was dependent solely on natural cycles. Nature gave and nature took away. It was our job to make the best use of the resources available, and they were plentiful. We now have greater powers either to destroy or improve the environment. Resource availability and quality are greatly determined by the policies we follow. And those policies in turn are greatly influenced by how well we understand the many areas that make up the environment. *Environmental Trends* is one effort to add to our understanding and share what we have found.

Chapter 1

People and the Land

The United States is the fourth largest country in the world both in land size and population.

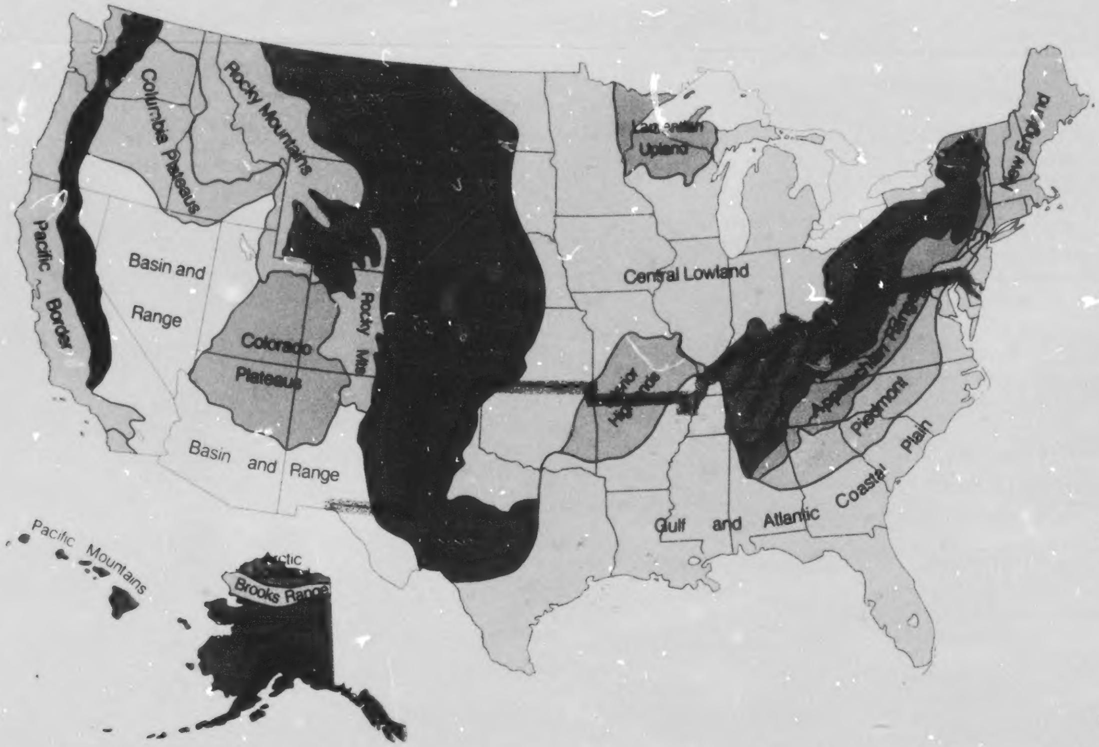
It contains more than 3.5 million square miles of land and, in mid-1979, 220 million people.

It incorporates the major meteorological, topographical, and ecological areas of the earth.

Its land is rich and exceedingly diverse.

1-1

Physical characteristics of the United States


Columbia Plateaus
Rocky Mountains
Laurentian Upland
New England
Pacific Border
Basin and Range
Central Lowland
Colorado Plateaus
Rocky Mts
Interior Highlands
Appalachian Ranges
Piedmont
Coastal Plain
Basin and Range
Gulf and Atlantic
Pacific Mountains
Arctic
Brooks Range

The West stretches from New Mexico to Washington and includes Alaska and Hawaii. The Rocky Mountains determine the topography and climate of much of the area. Because of the mountainous character of the West, there is intense competition for level land between urban and agricultural uses. Water is in short supply in many parts, and much of the cropland is irrigated. Population density in the West is lower than in other areas, but more westerners live in urban areas than do residents of other parts of the country. Much of the land (63%) is owned by the Federal Government.

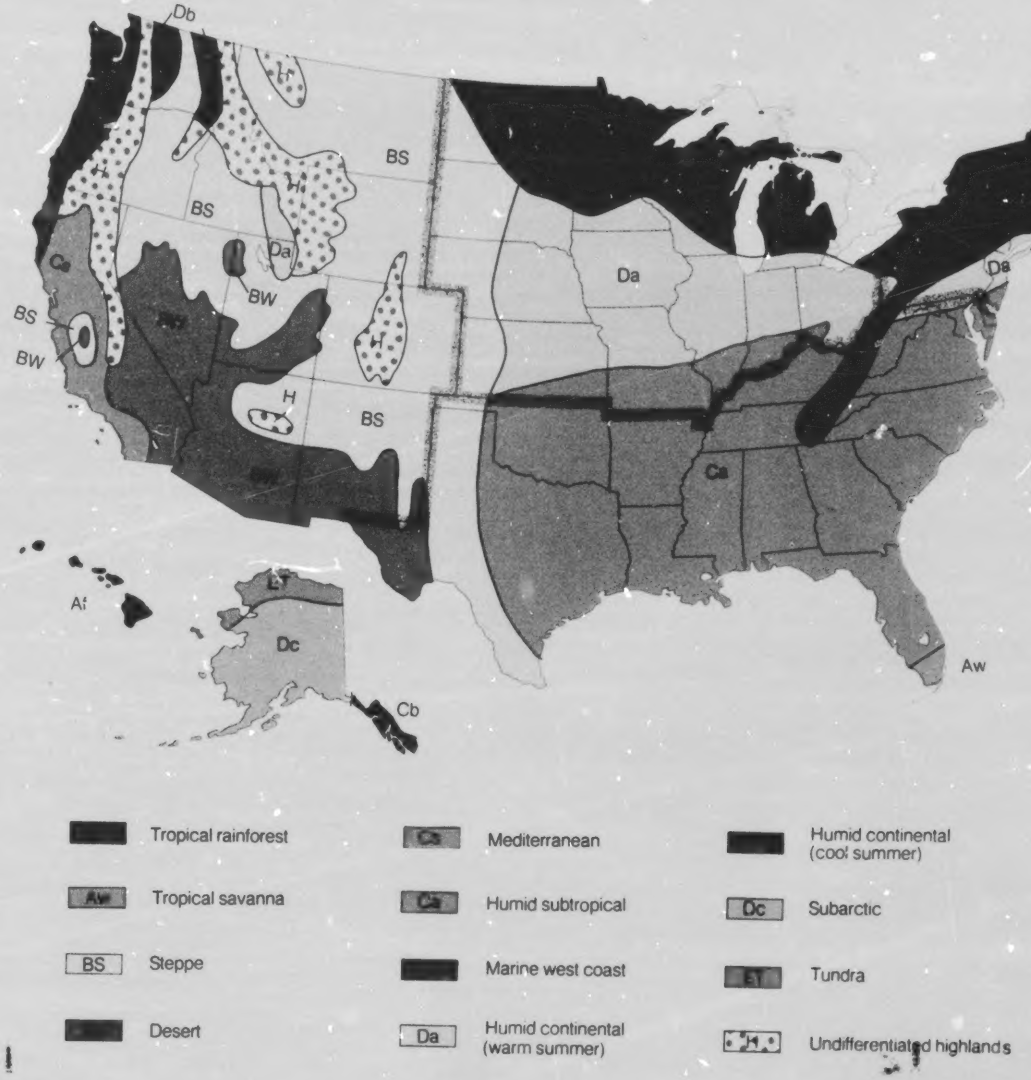
The North Central States, from North Dakota to Missouri and east to Ohio, are generally flat, with extensive deposits of black organic-rich soil. The climate is humid continental, with long winters and short, cool summers. The area is characterized by large industrial cities and an extensive hinterland set out in medium-size farms. The North Central area has more small towns than any other part of the United States. Population centers in this area are generally near lakes and major rivers.

The South extends from Maryland south to Florida and west to Texas. The climate is humid subtropical except for the southern tip of Florida and the Keys, which are the only tropical areas of the United States. The Appalachian Mountains and their slopes dominate the central part of the region. Much of the peripheral area is coastal or other lowland. Some of the most productive U.S. lands are along the southern coastal area, lands that are habitat for over one-third of the threatened and endangered species in the United States.

The Northeast, from Maine to Pennsylvania, is primarily in the humid continental climatic zone, with short, cool summers and moderate annual rainfall. Much of the land was once glaciated and is characterized by rocky soil. Its population density is the highest in the United States, but the region retains thousands of acres of wilderness.

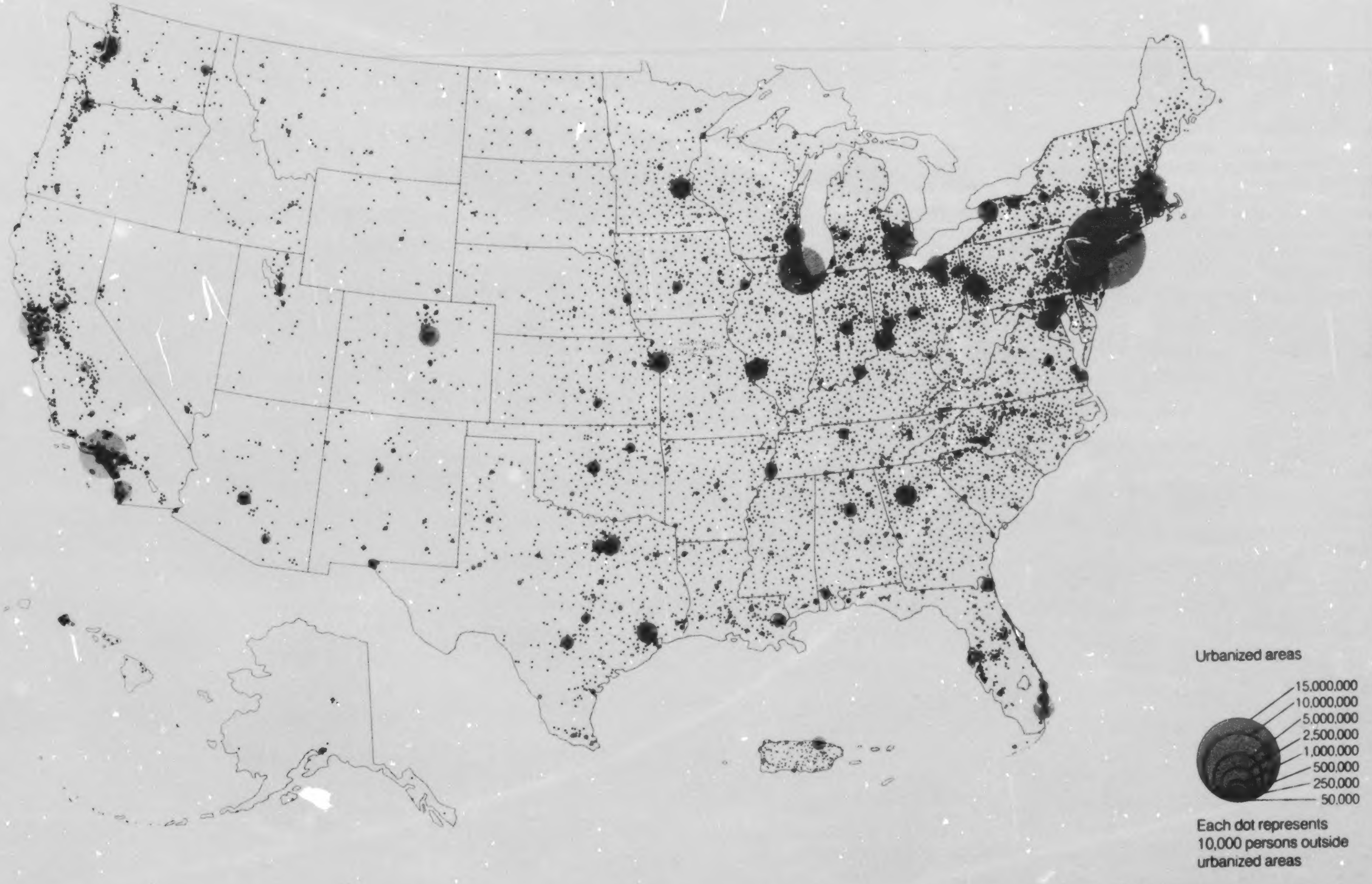
1-2

Climatic zones of the United States


Db
H
BS
Cs
BS
BW
BW
BW
Da
H
BS
H
BS
Da
Da
Ca
Aw
Af
ET
Dc
Cb
Tropical rainforest
Aw Tropical savanna
BS Steppe
Desert
Cs Mediterranean
Ca Humid subtropical
Marine west coast
Da Humid continental (warm summer)
Humid continental (cool summer)
Dc Subarctic
ET Tundra
H Undifferentiated highlands

1-3

Population distribution, 1970

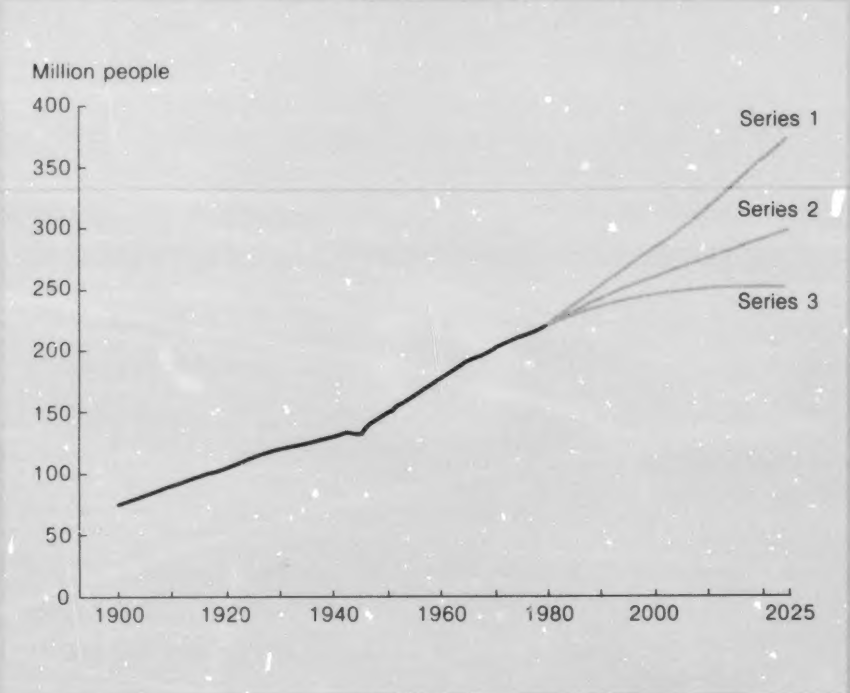

Urbanized areas
15,000,000
10,000,000
5,000,000
2,500,000
1,000,000
500,000
250,000
50,000

Each dot represents 10,000 persons outside urbanized areas

16

17 31

1-4
Total population, 1900-1978, and projected to 2025

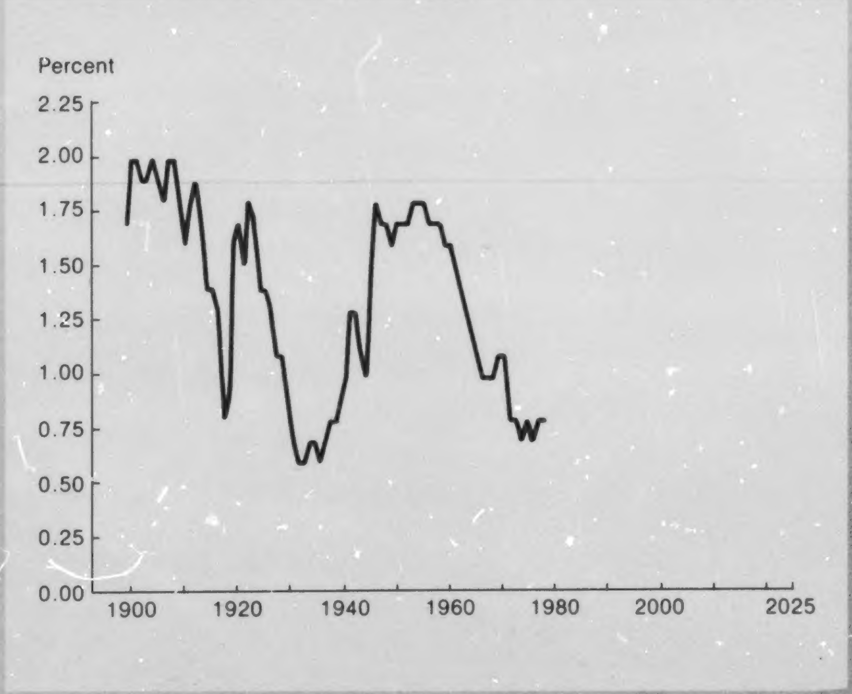


Most of the 220 million people in the United States live in urban areas. Nearly three-fourths (73%) live in cities and towns of 2,500 or more. This means that 73% of the people live on less than 2% of the land.

The population of the United States is growing by about 1.7 million each year. Total growth is projected at 42 million for the remaining years of the 20th century. According to the Series 2 projection, the population will reach 260 million in the year 2000.

☐ The three projection series are based on different assumptions about the level of completed cohort fertility, that is, the average number of births a woman has in her lifetime. Series 1 assumes a total fertility of 2.7 births per woman; Series 2, 2.1; and Series 3, 1.7. In 1978, the rate was 1.8.

1-5
Population growth rates, 1900-1978

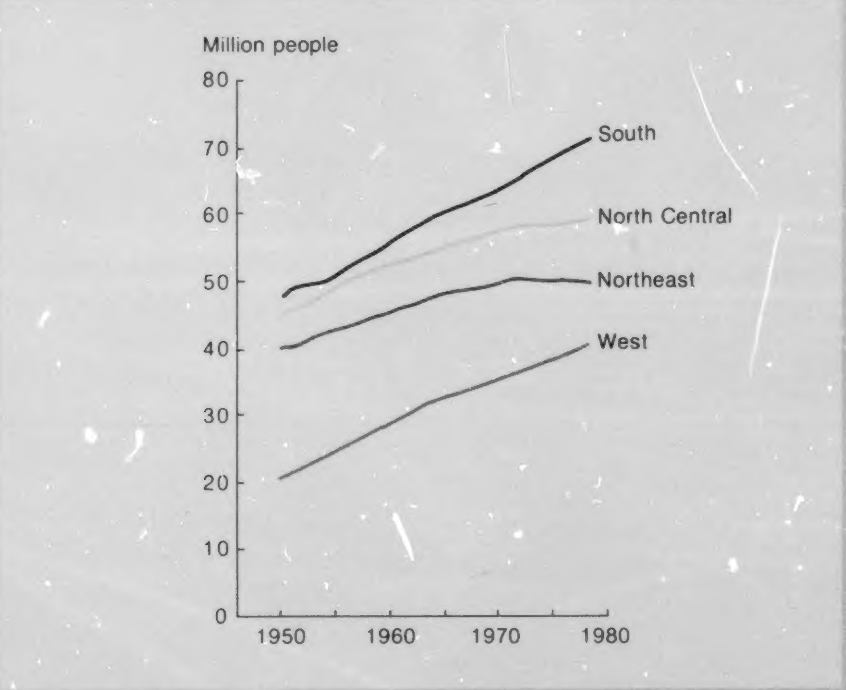


The population appears to be growing inexorably—the lines on the charts seem always to go up, but the *rate* of growth has declined. In 1978, it was only 0.8%. If current trends continue, zero population growth—the point at which the population simply replaces itself—could be reached by the year 2025.

The main reason for this decline is the decrease in the number of births. On the average, women now have only 1.8 children. In 1940, the average was 2.5. In the late 1950s, it was 3.6.

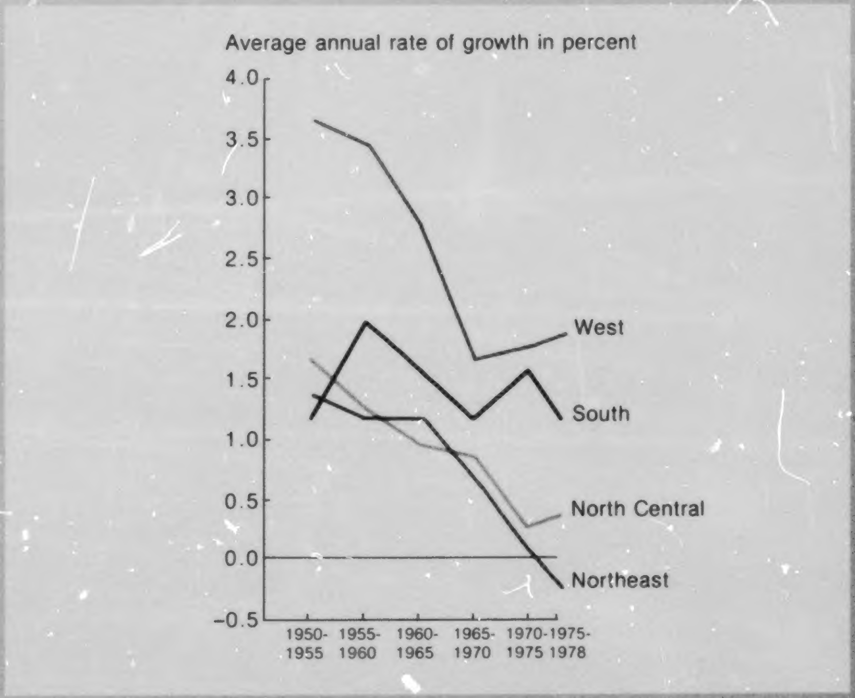
☐ Three distinct social phenomena influence the rate of population growth: the birth rate, the death rate, and the rate of immigration. In recent years the birth rate has dropped to its lowest level, but the death rate has remained relatively steady. The immigration rate is not easily determined. Registered immigrants number about 400,000 per year, but many are not counted in the official statistics of the Immigration and Naturalization Service. Estimates of the unregistered immigrants run as high as 1.4 million per year.

1-6
Population, by region, 1950-1978



The fastest growing regions of the country are the South and the West. The South is the most populous as well. For the first time in history, more people now live in the South and the West than elsewhere in the country. The main reason for this regional shift in population growth is migration.

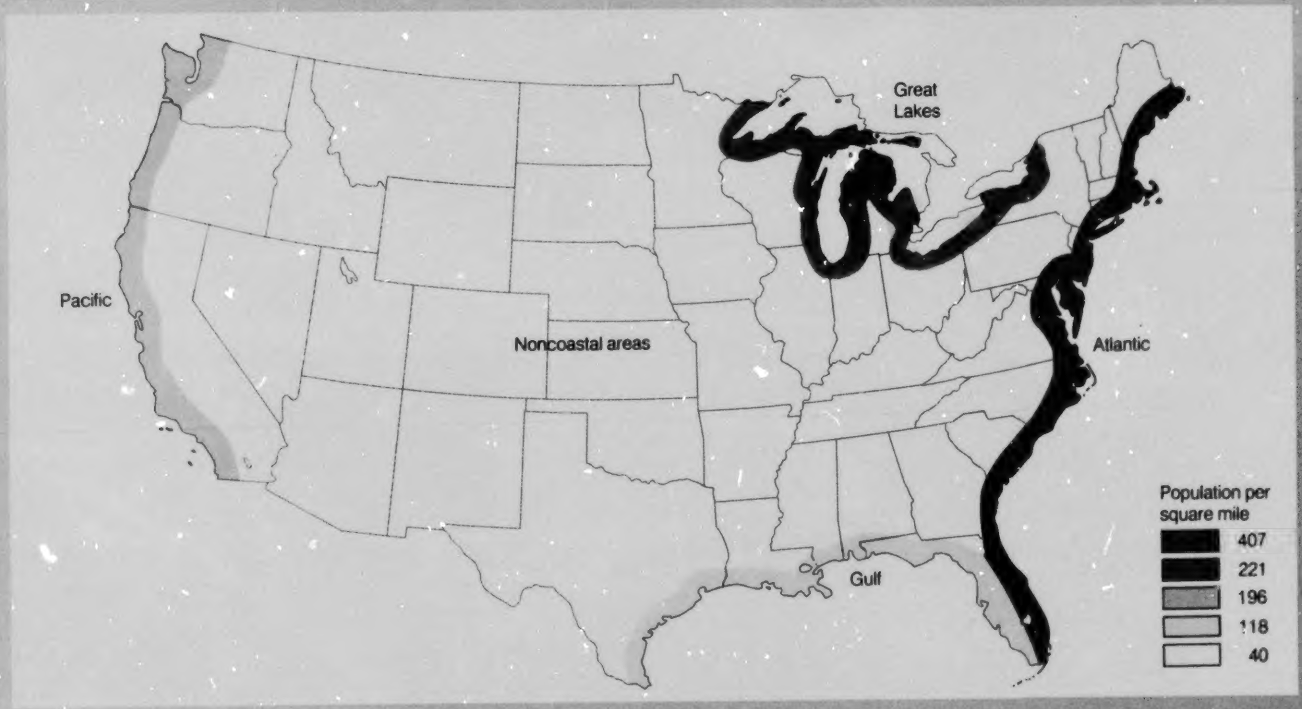
1-7
Population growth rates, by region, 1950-1978



The West has the highest growth rate, but it has slowed considerably, largely because of decreased migration to California. The fastest growing States of the West are Arizona, Nevada, and Wyoming.

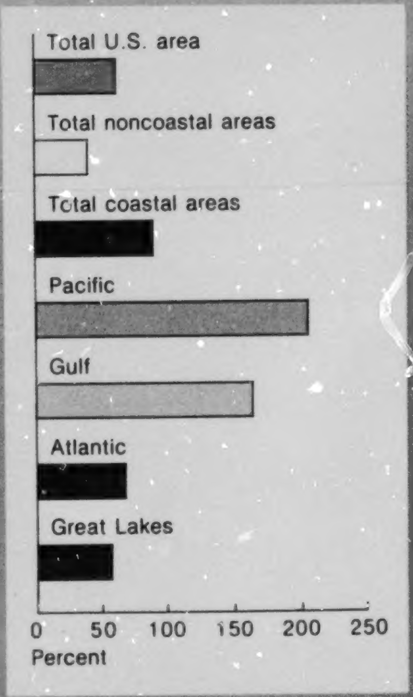
The South has the second highest growth rate. The Northeast has a negative rate of growth, with an average annual population loss of 0.2% between 1975 and 1978.

1-8
Population density along major coasts, 1976


Great Lakes
Pacific
Noncoastal areas
Atlantic
Gulf
Population per square mile
407
221
196
118
40

Another dominant pattern of population distribution has been the move to coastal areas. In 1976, nearly 53% of the population lived within 50 miles of a major coast. The density in these areas was six times that of the rest of the country.

1-9
Increase in population density along major coasts, 1940-1976

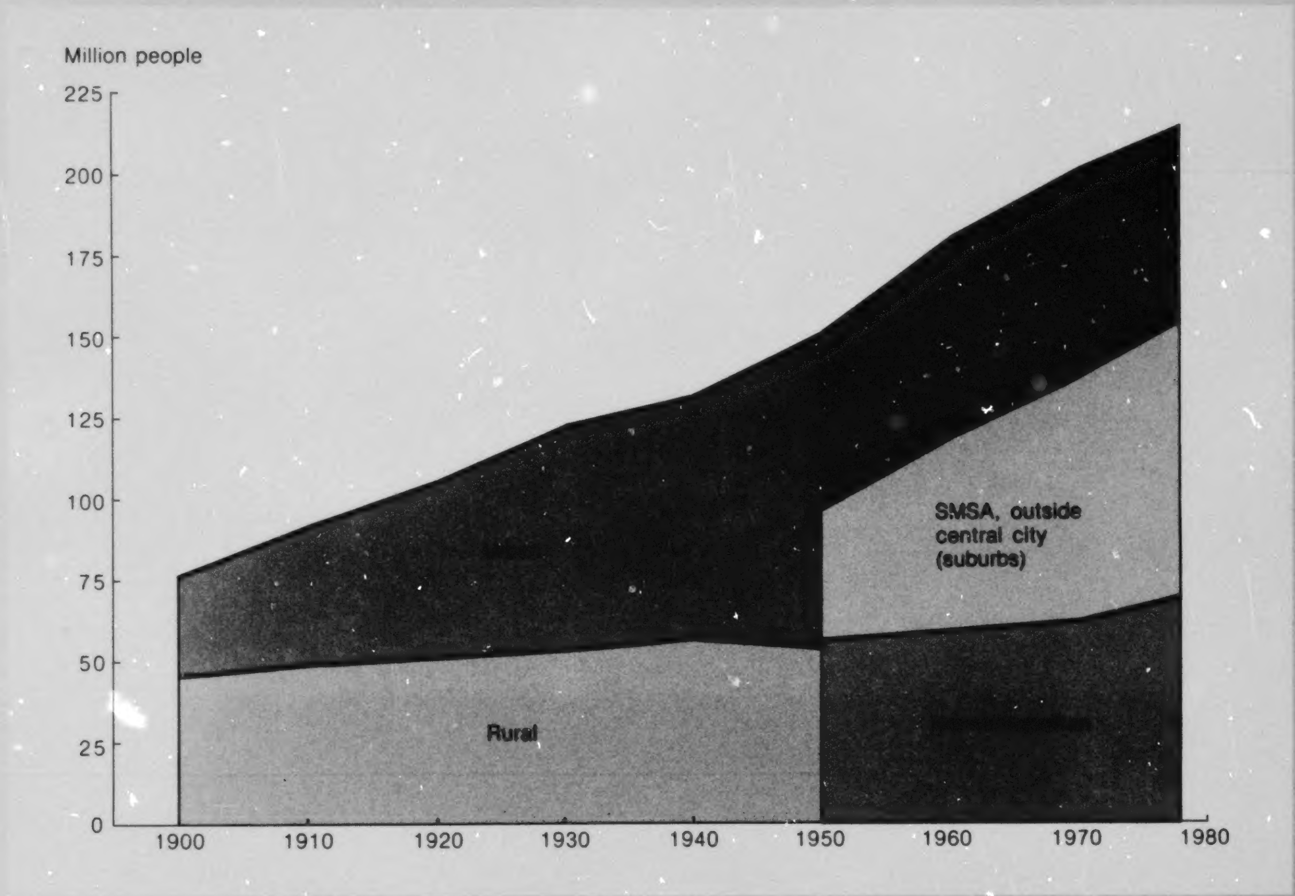


The most rapidly growing coastal areas have been the Gulf of Mexico and the Pacific.

22 19 023

1-10

Population in urban and rural areas, 1900-1950, and in metropolitan and nonmetropolitan areas, 1950-1978

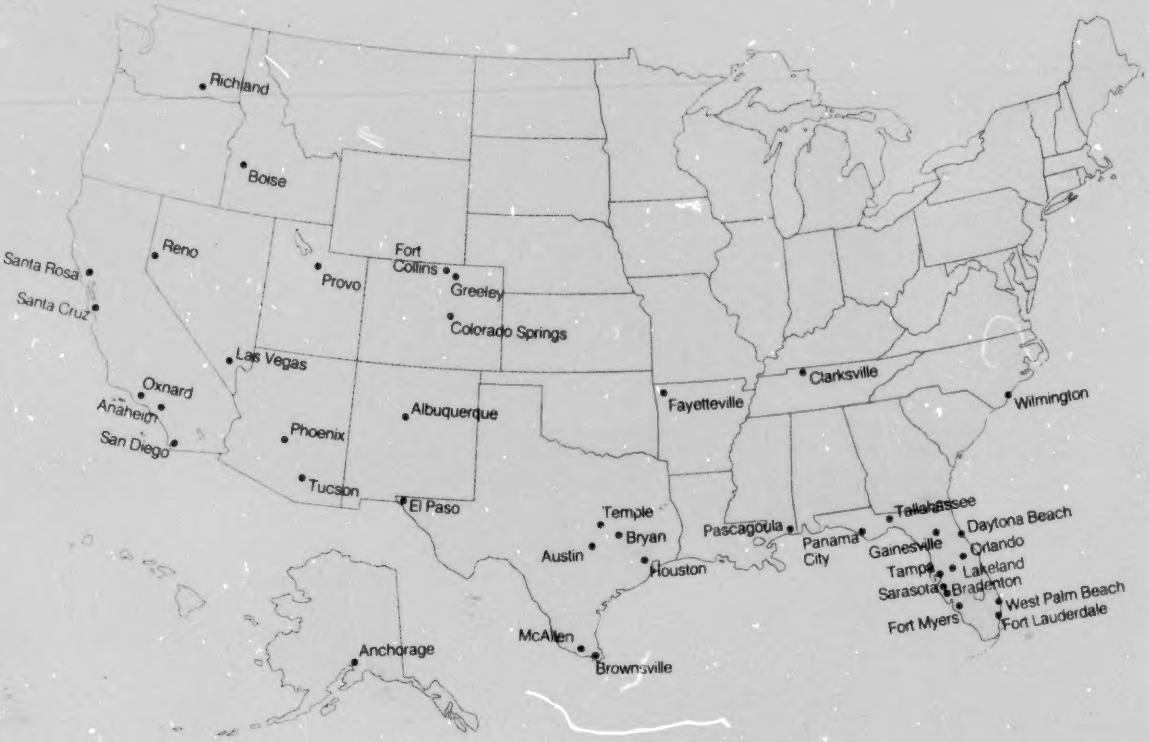


Most people in the United States live in large metropolitan areas, which for the purpose of measurement are identified as Standard Metropolitan Statistical Areas (SMSAs). In 1978, about 67% of the population lived in SMSAs.

☐ An SMSA is an area with an urban center of 50,000 persons or more, including the county containing that center and neighboring counties closely associated with the central area by daily commuting ties. SMSAs contain not only urban areas, which occupy 10% of the land, but also open space, forests, recreation areas, parks, and cropland.

1-11

Metropolitan areas with population increases of 20% or more, 1970-1977


Richland
Boise
Reno
Santa Rosa
Santa Cruz
Provo
Fort Collins
Greeley
Colorado Springs
Las Vegas
Oxnard
Anaheim
San Diego
Phoenix
Albuquerque
Tucson
El Paso
Fayetteville
Clarksville
Wilmington
Temple
Bryan
Austin
Houston
Pascagoula
Panama City
Tallahassee
Daytona Beach
Gainesville
Orlando
Tampa
Lakeland
Sarasota
Bradenton
West Palm Beach
Fort Myers
Fort Lauderdale
McAllen
Brownsville
Anchorage

The metropolitan areas that are growing the fastest are in the South and West. In contrast, almost all that are losing population are in the Northeast and North Central States.

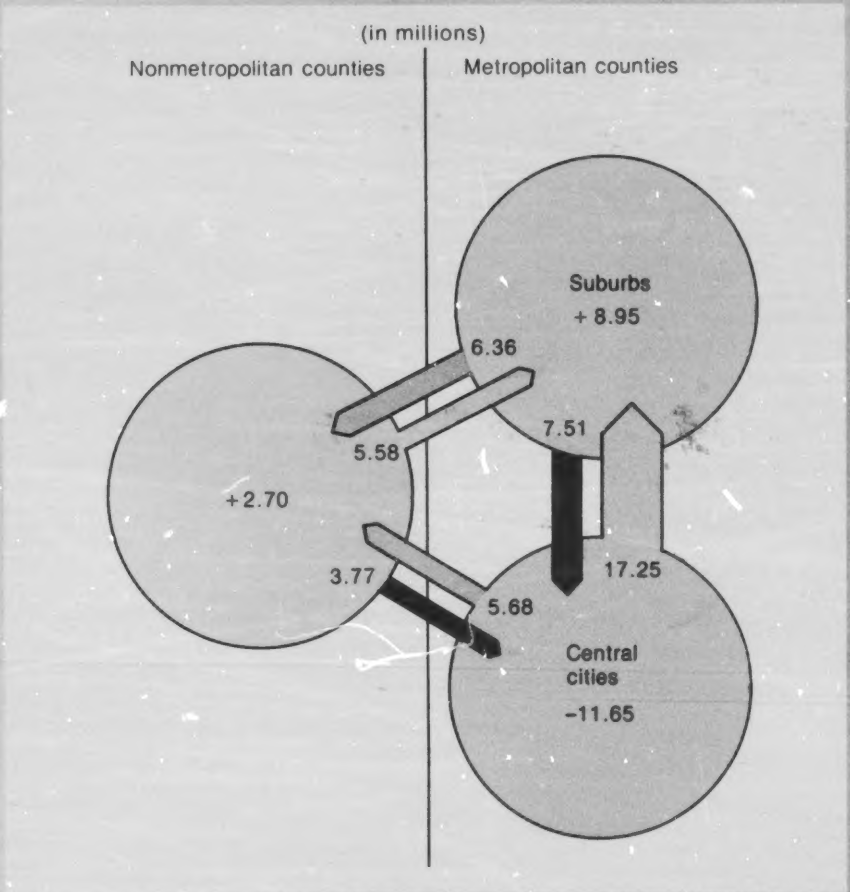
Of the 40 fastest growing areas, 12 are in Florida.

The increasing migration to the South and West and the rapid movement to coastal areas during the 1960s and 1970s severely strain area resources, particularly wildlife habitat not previously affected by manmade structures or economic and social development.

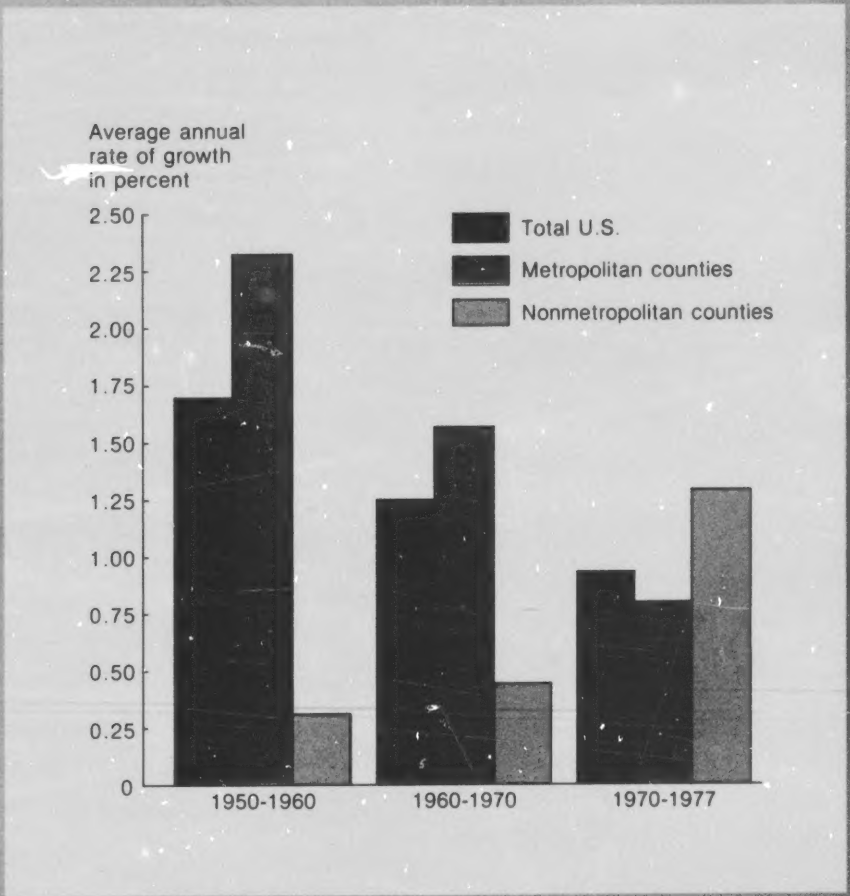
Further, there is every indication that some ecosystems, particularly in arid and semiarid regions of the West and wetlands of the South, are more sensitive to change and modification than those of the plains, forests, and croplands of the East and North.

PS

1-12
Population migration, 1970-1978


(in millions)
Nonmetropolitan counties
Metropolitan counties
Suburbs
+8.95
6.36
7.51
5.58
+2.70
3.77
5.68
17.25
Central cities
-11.65

1-13
Population growth rates in metropolitan and nonmetropolitan counties, 1950-1977



Another population trend is the migration out of large cities. Between 1970 and 1978, net emigration from central cities was 11.65 million.

Clearly, the U.S. population is shifting from large city living to smaller and medium-size city and suburban life. In 1930, for example, almost 12.2% of the population lived in cities of 1 million or more. By 1970, the figure was 9.2%; by 1976, it was estimated at 8.3%.

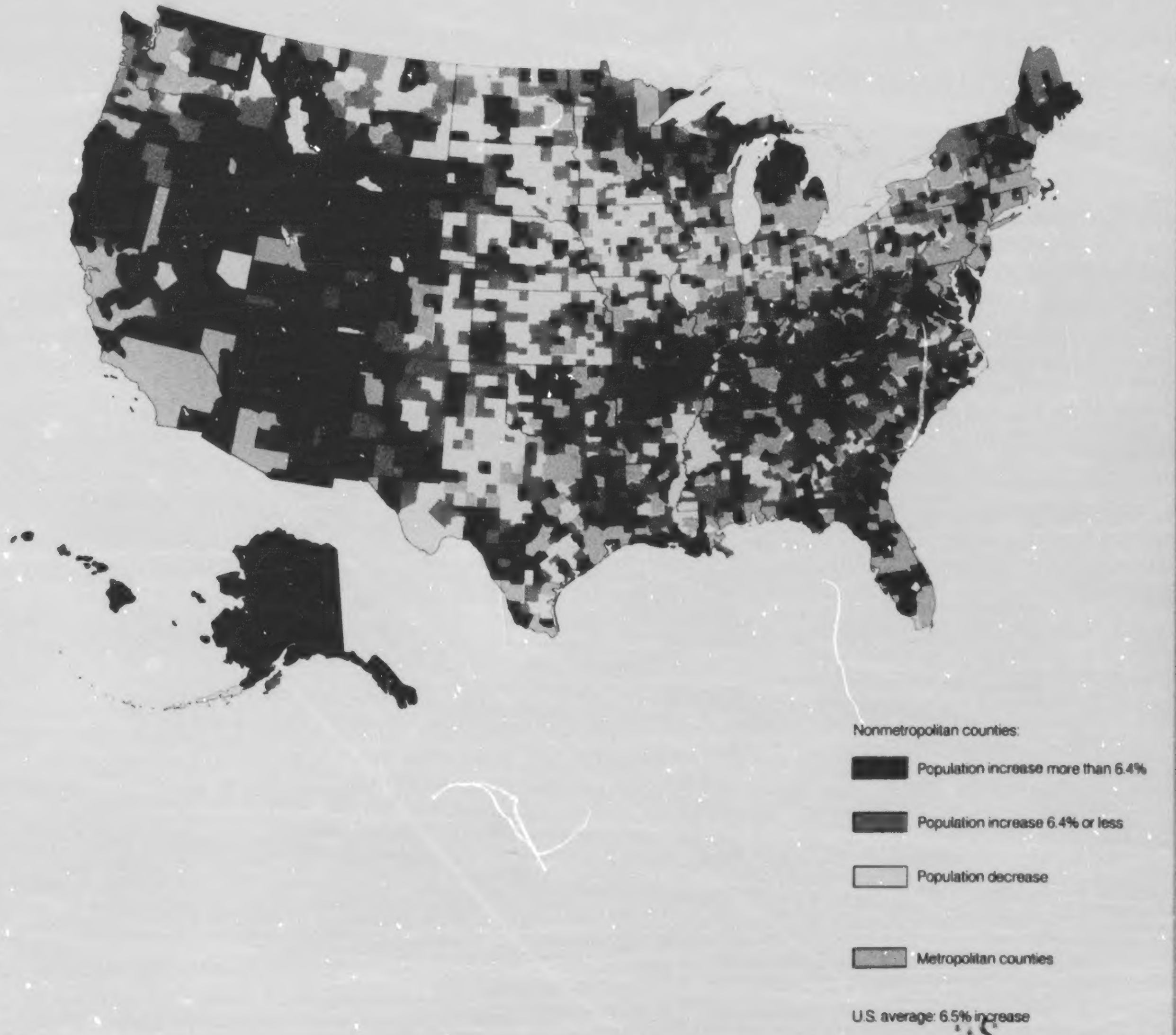
Most of the people moving out of the cities are moving to the suburbs. But many are going to more rural areas, so many that nonmetropolitan counties gained 2.7 million people from migration between 1970 and 1978. For the first time in U.S. history, nonmetropolitan counties are growing faster than metropolitan counties.

☐ In 1979, 2,466 of the 3,141 counties (79%) were nonmetropolitan, that is, not part of an SMSA. As of 1978, they contained 33% of the population.

1-14
Population change in nonmetropolitan counties, 1970-1977

The shift from cities and suburbs to more rural areas is taking place in almost every State, but it is pronounced in the Ozarks, the Tennessee Valley, the Texas hill country, northern Michigan, and the Rockies.

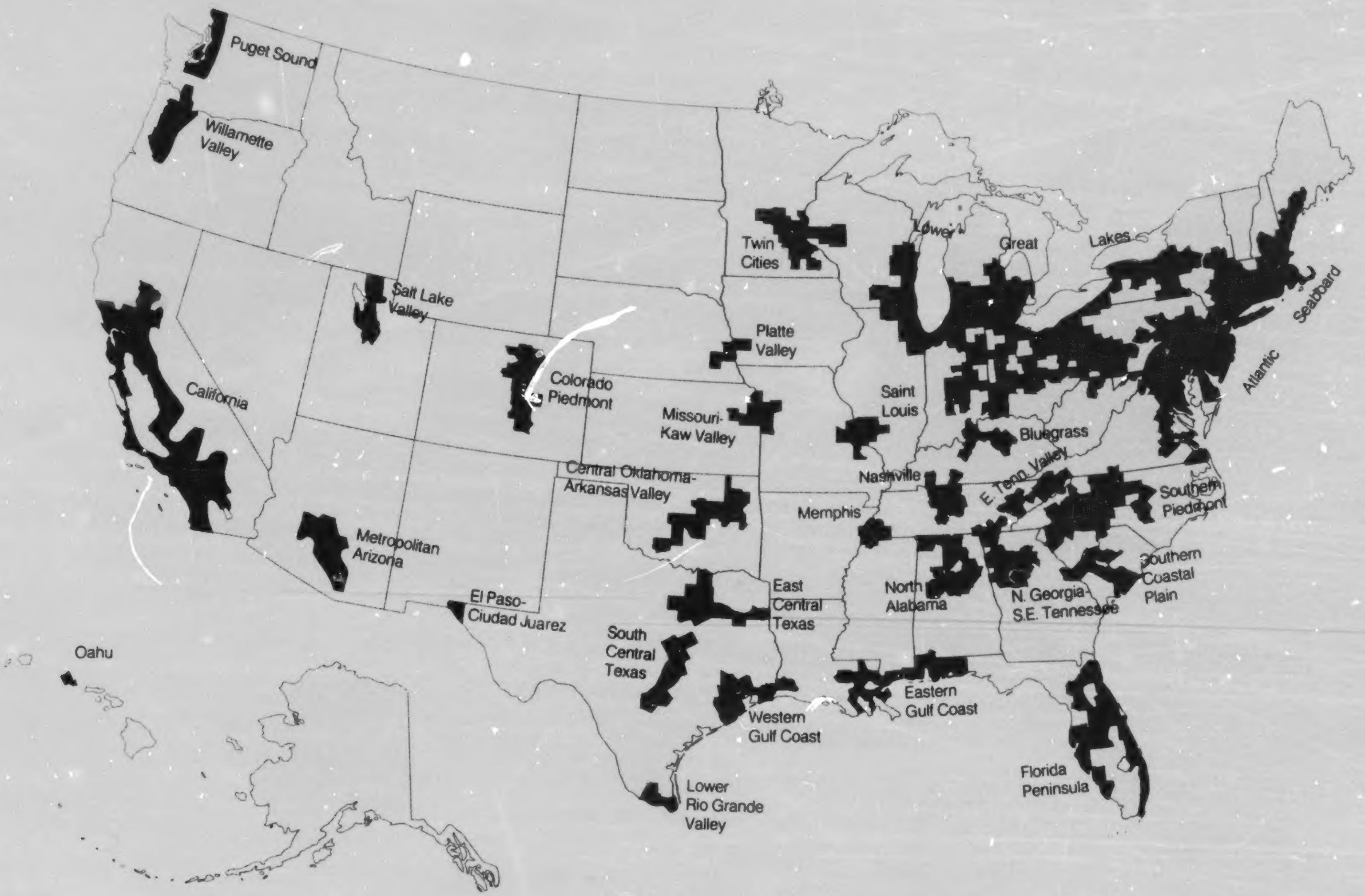
It is too soon to tell if the movement to nonmetropolitan counties will merely create new centers of rapid population growth or lead to a more scattered land use pattern that could be called rural growth.


Nonmetropolitan counties:
■ Population increase more than 6.4%
▨ Population increase 6.4% or less
☐ Population decrease
▒ Metropolitan counties
U.S. average: 6.5% increase

28

29

1-15
Urban regions, 2000


Puget Sound
Willamette Valley
Salt Lake Valley
California
Colorado Piedmont
Metropolitan Arizona
El Paso-Ciudad Juarez
Oahu
Twin Cities
Platte Valley
Missouri-Kaw Valley
Central Oklahoma-Arkansas Valley
South Central Texas
East Central Texas
Western Gulf Coast
Lower Rio Grande Valley
Saint Louis
Memphis
Nashville
Lower Great Lakes
Atlantic Seaboard
Bluegrass
E. Tenn. Valley
Southern Piedmont
North Alabama
N. Georgia-S.E. Tennessee
Southern Coastal Plain
Eastern Gulf Coast
Florida Peninsula

If population trends continue, there will be about 260 million people in the United States in the year 2000. Three-quarters of them are expected to live in 29 distinct urban regions.

An urban region is a large area dominated by metropolitan and urban centers and containing at least 1 million people. An urban region is not a super city. Rather, it is defined by a relatively dense population and one or more metropolitan areas, with park, recreation, crop, and forest land in addition to the built-up areas.

Sources and technical notes

1-1
Physical characteristics of the United States

The national atlas of the United States of America, U.S. Geological Survey (Washington, D.C., 1970), p. 61.

1-2
Climatic zones of the United States

Climatic chart of the world, U.S. Air Force, Aeronautic Chart and Information Center (St. Louis, Mo., 1965), reprinted from *World atlas: Physical, political, and economic*, Edward B. Espenshade, Jr., ed. (Chicago: Rand McNally and Co., 1957). Copyright by Rand McNally and Co., R.L. 81-Y-31.

Köeppen's classification of climates is based on monthly and annual averages of temperature and precipitation. Each climatic division is designated by a series of letters. The first letter corresponds to one of five major divisions: A, rainy climates with no winters; B, dry climates; C, rainy climates with mild winters; D, rainy climates with severe winters; and E, polar climates with no warm season.

A second capital letter subdivides two of the five divisions: BS, dry grassland or steppes; BW, desert; ET, tundra; and EF, continuous frost.

Small letters are used to indicate seasonal variation in temperature and precipitation: f, moist; w, winter dry; s, summer dry; a, hot summers, temperature of warmest month is greater than 71.6°F (22°C); b, cool summers, temperature of the warmest month under 71.6°F (22°C), but with at least four months above 50°F (10°C); c, cool short summers, only one to three months above 50°F (10°C); and so forth. For further details, see *An outline of geography*, Preston E. James (Boston: Ginn and Company, 1943), pp. 370–379.

1-3
Population distribution, 1970

Graphic summary of the 1970 population census, U.S. Bureau of the Census (Washington: USGPO, 1973), suppl. rep. PC(SI)-55, p. 15.

The 1970 census definition of urban population includes places with 2,500 or more residents.

1-4
Total population, 1900–1978, and projected to 2025

1900–1977: *Statistical abstract of the United States: 1978*, U.S Bureau of the Census (Washington: USGPO, 1978), table 2, p. 6.

1978: *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1978), series P-25, n. 729.

1980–2025: *Current population reports* (Washington: USGPO, 1977), series P-25, n. 704, table D, p. 6.

Data are as of July 1 of the year noted.

Data for 1900–1978 exclude Armed Forces overseas.

Projections to 2025 include Armed Forces overseas.

1-5
Population growth rates, 1900–1978

1900–1909: *Statistical abstract of the United States: 1976*, U.S. Bureau of the Census (Washington: USGPO, 1976), table 2, p. 5.

1910–1969: *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1973), series P-25, n. 499, tables A, 4, pp. 1, 11, in *Social indicators, 1973*, U.S. Office of Management and Budget (Washington: USGPO, 1973), pp. 246, 249.

1970–1977: *Statistical abstract of the United States: 1978* (Washington: USGPO, 1978), table 2, p. 6.

1978: *Current population reports* (Washington: USGPO, 1978), series P-25, n. 729.

Rates are based on the population change during the calendar year as a percentage of the midyear population.

Prior to 1940, data exclude Alaska, Hawaii, and Armed Forces overseas, except for 1917–1919, when Armed Forces overseas were included.

Beginning in 1940, data for total U.S. population include Armed Forces overseas.

1-6
Population, by region, 1950–1978

1950–1959: *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1965), series P-25, n. 304, table 2, p. 10.

1960–1969: *Current population reports* (Washington: USGPO, 1971), series P-25, n. 460, table 1, p. 8.

1970–1976: *Current population reports* (Washington: USGPO, 1978), series P-25, n. 727, table 3, p. 7.

1977–1978: *Current population reports* (Washington: USGPO, 1978), series P-25, n. 790, table 1, p. 2.

1-7
Population growth rates, by region, 1950–1978

See 1-6.

1-8
Population density along major coasts, 1976

Statistical abstract of the United States: 1978, U.S. Bureau of the Census (Washington: USGPO, 1978), table 7, p. 10.

1-9
Increase in population density along major coasts, 1940–1976

See 1-8.

1-10
Population in urban and rural areas, 1900–1950, and in metropolitan and nonmetropolitan areas, 1950–1978

Urban and rural: *Historical statistics of the United States, colonial times to 1970*, U.S. Bureau of the Census (Washington: USGPO, 1975), p. 12.

Metropolitan and nonmetropolitan, 1950 and 1960: *Statistical abstract of the United States: 1976*, U.S. Bureau of the Census (Washington: USGPO, 1976), table 15, p. 16. 1970 and 1978: *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1979), series P-20, n. 336, table 19, p. 34.

Each Standard Metropolitan Statistical Area (SMSA) is divided into two areas: "central city" and "outside the central city." The largest city within each SMSA is usually designated the "central city." The remainder of the SMSA is "outside the central city." This remaining area may include cities of 50,000 or more and may be located in more than one State. Areas of the country that do not meet the SMSA criteria are designated nonmetropolitan.

In addition to the county or counties containing such a city or cities, contiguous counties are included in an SMSA if, according to certain criteria, they are socially and economically integrated with the central county. In New England, SMSAs consist of towns and cities rather than counties.

The 1950–1978 data include residents of the 243 SMSAs as defined in the 1970 Census of Population. The 1970 and 1978 data include civilian noninstitutional residents only.

1-11
Metropolitan areas with population increases of 20% or more, 1970–1977

Current population reports, U.S. Bureau of the Census (Washington: USGPO, 1979), series P-25, n. 810, table 1, pp. 4–24.

1-12
Population migration, 1970–1978

Current population reports, U.S. Bureau of the Census (Washington: USGPO, 1975), series P-20, n. 285, p. 2.

Current population reports (Washington: USGPO, 1978), series P-20, n. 331, table 1, p. 5.

Details may not add to total because of rounding.

1-13
Population growth rates in metropolitan and nonmetropolitan counties, 1950–1977

1950–1970: "The new pattern of nonmetropolitan population change," Calvin L. Beale and Glenn V. Fuguitt, University of Wisconsin, Center for Demography and Ecology, 1975.

1970–1977: "Trends in metropolitan and nonmetropolitan population growth since 1970," Richard L. Forstall, U.S. Bureau of the Census, 1975. *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1979), series P-25, n. 810, tables 6, 7, pp. 30, 31.

1-14
Population change in nonmetropolitan counties, 1970–1977

Social and economic trends in rural America, USDA Economics, Statistics, and Cooperatives Service (Washington, D.C., 1979), p. 13.

1-15
Urban regions, 2000

Jerome P. Pickard, Appalachian Regional Commission, Washington, D.C.

Two urban regions, the Lower Rio Grande Valley and El Paso–Ciudad Juarez, are international and include area and population in Mexico.

Chapter 2

Critical Areas

Critical areas are ecologically and culturally important areas that must be protected to maintain their natural or present condition. They are unique or are in limited supply, and they are fragile. Without protection and control, they will be lost forever or will be so changed that they can be restored only at considerable expense in time and money.

Five kinds of critical areas are examined here: Wetlands, wild areas, parks, historic places, and risk zones, where land and communities are continually threatened by natural disasters.

Wetlands

Wetlands occupy a unique niche in the ecology and topography of the land. Often, they are the small but very important transition areas where water and land come together.

Wetlands—the marshes, swamps, bogs, potholes, wet meadows, and river-overflow land—are lowlands that are waterlogged or covered with stagnant or slow-moving water. They exist in shallow lakes and ponds, along river banks, and in coastal areas.

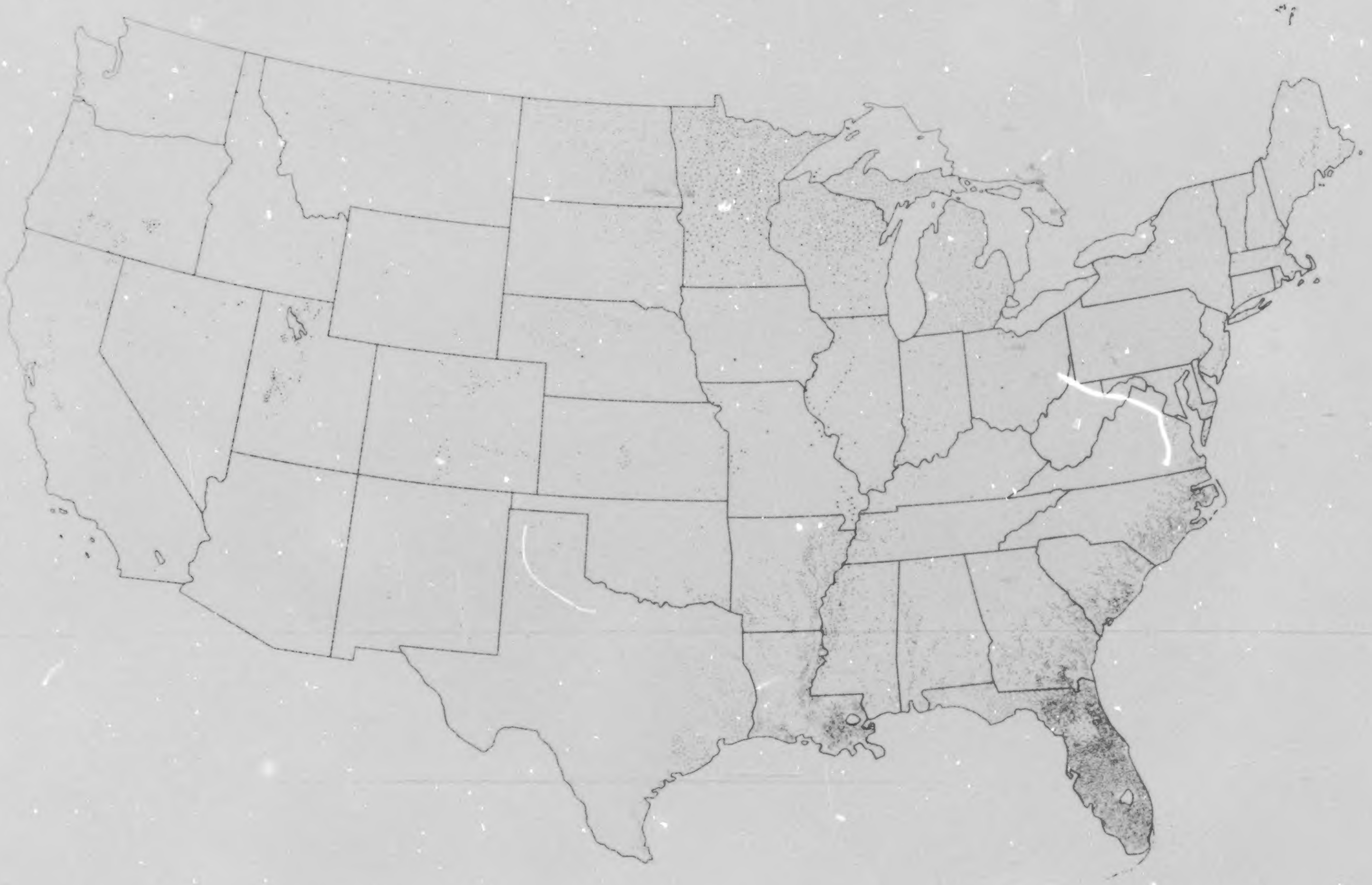
Wetlands act as giant sponges that absorb impurities, stabilize water flow, and provide a home for the many forms of life so important in the life cycles of fish and birds. More specifically, they may provide groundwater recharge, retention of surface water, stabilization of runoff (reducing flood waters), reduction or prevention of erosion, creation of firebreaks, food for fish downstream, and production of cash crops such as timber, marsh hay, wild rice, blueberries, cranberries, and peat moss. They act as natural purifiers of polluted water, with plants and animals living in the wetlands reducing the excess nutrient load.

Because their usefulness is not always obvious, many wetlands have been filled or dredged. Only recently has their importance been recognized and measures taken to protect them.

2-1
Natural wetlands, 1954

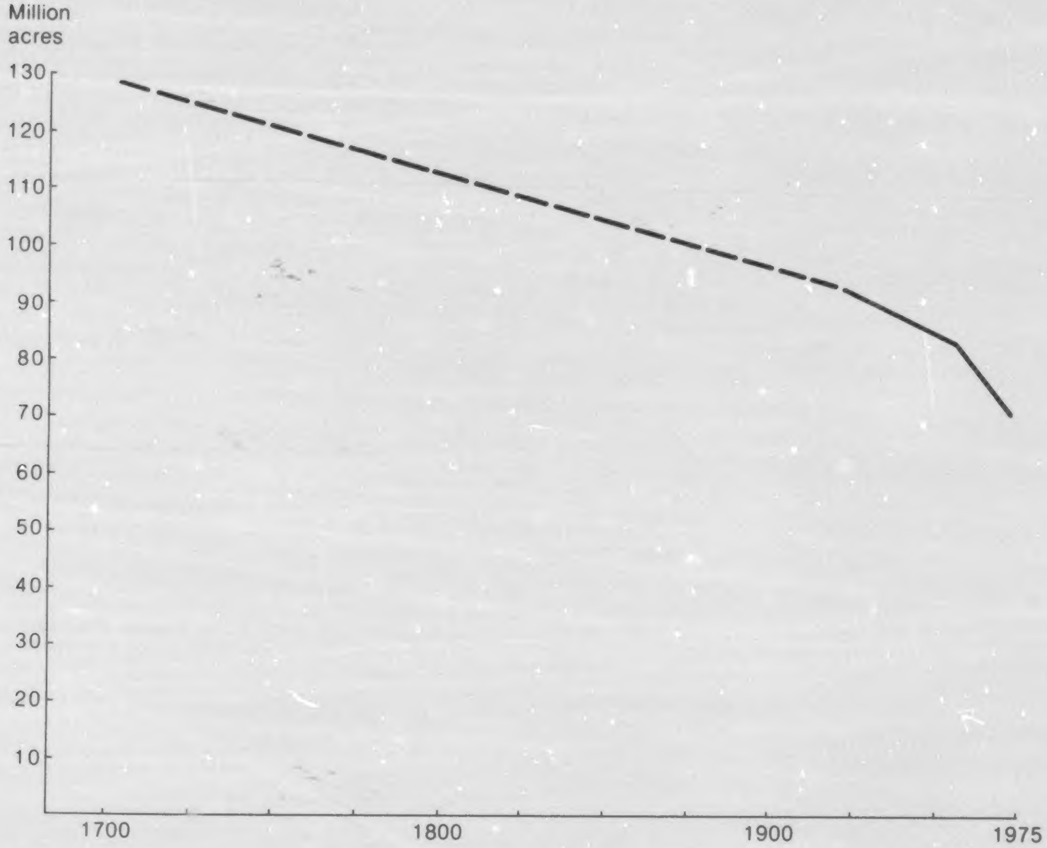
There are wetlands in every State, but the most extensive areas are in Florida, along the lower Mississippi River, in the lowlands of the Atlantic and Gulf coasts, and in the forest and marshlands of northern Wisconsin and Minnesota.

Originally, wetlands were found along almost the entire Atlantic and Gulf coasts, but development has slowly changed many of these wetlands into dry land or navigable water.



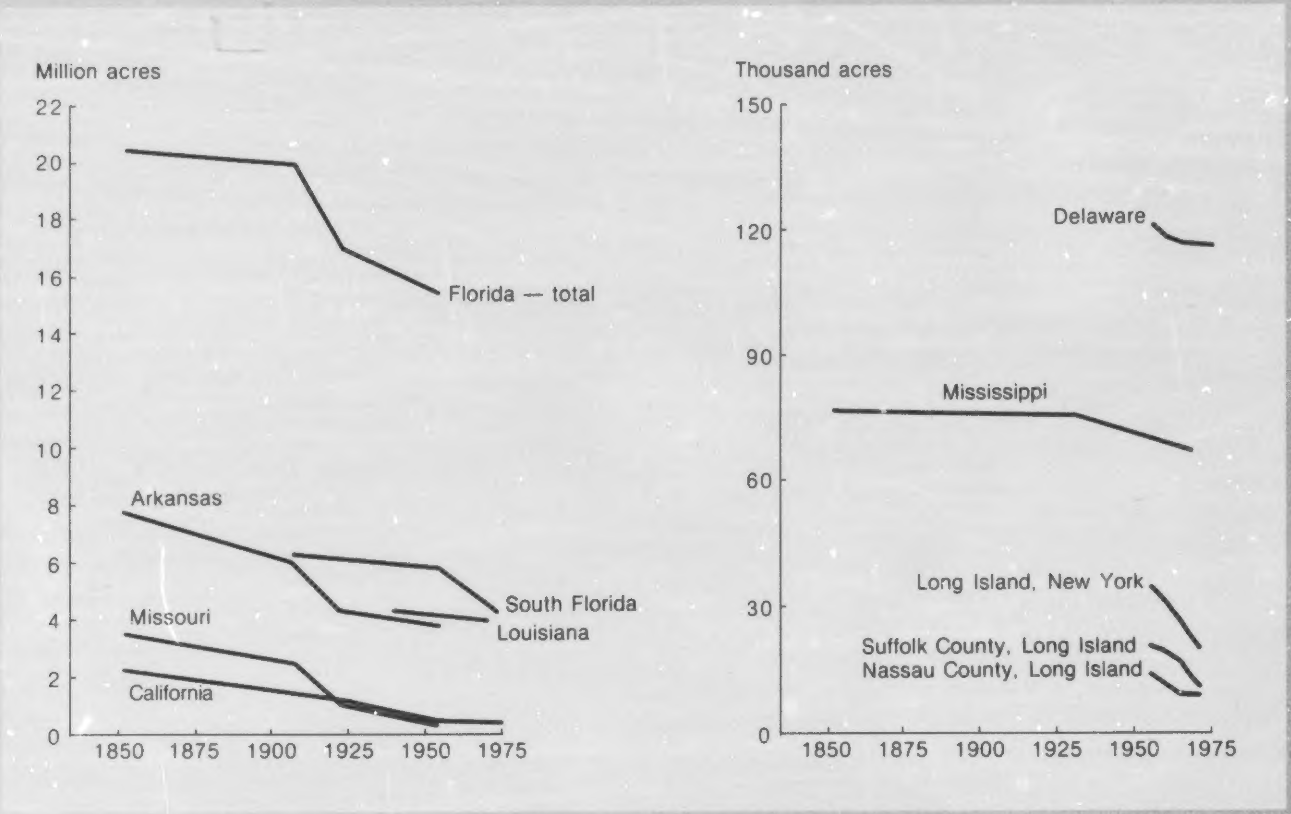
Dots represent natural wetlands of significant value to fish and wildlife

2-2
Total wetland acreage, presettlement to 1971



Barely more than half the original wetland acreage remains. In 1971, there were roughly 70 million acres. Since the mid-1950s, an average of more than 600,000 acres of wetlands has been lost each year.

2-3
Wetland acreages, selected States, 1850–1975



Florida contains the largest acreage of remaining wetlands, roughly 20% of the U.S. total.

Arkansas has lost half of its wetlands.

South Florida has lost a fourth of its wetlands in the past 20 years. State legislation passed in 1972 now regulates the use of wetlands.

Because of agricultural and industrial development, Louisiana's coastal wetlands are disappearing. A 1978 coastal zone management law regulates most uses of wetlands through a permit system.

Only a tenth of Missouri's wetlands remain.

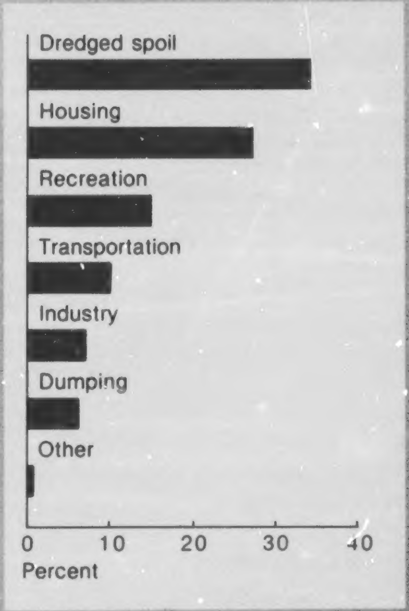
Most of California's wetlands have been destroyed. Remaining lands are protected by the 1972 Coastal Conservation Act, which requires a permit for development.

Losses in Delaware are leveling off as a result of strict control. No heavy industrial development is permitted in the coastal zone.

Most damage to Mississippi coastal wetlands has occurred in the past 45 years. Coastal wetlands are now partially protected through a law that requires permits for dredging.

Tidal wetlands in New York are disappearing rapidly. The rate of loss has slowed appreciably in Nassau County through strict control.

2-4
Use of filled wetlands, Maine to Delaware, 1955–1984



Along the Atlantic coast the single most extensive use of reclaimed wetlands has been for the development and maintenance of navigable waterways. Urban development—housing, roadways, recreation sites, and industrial sites—accounts for the remainder.

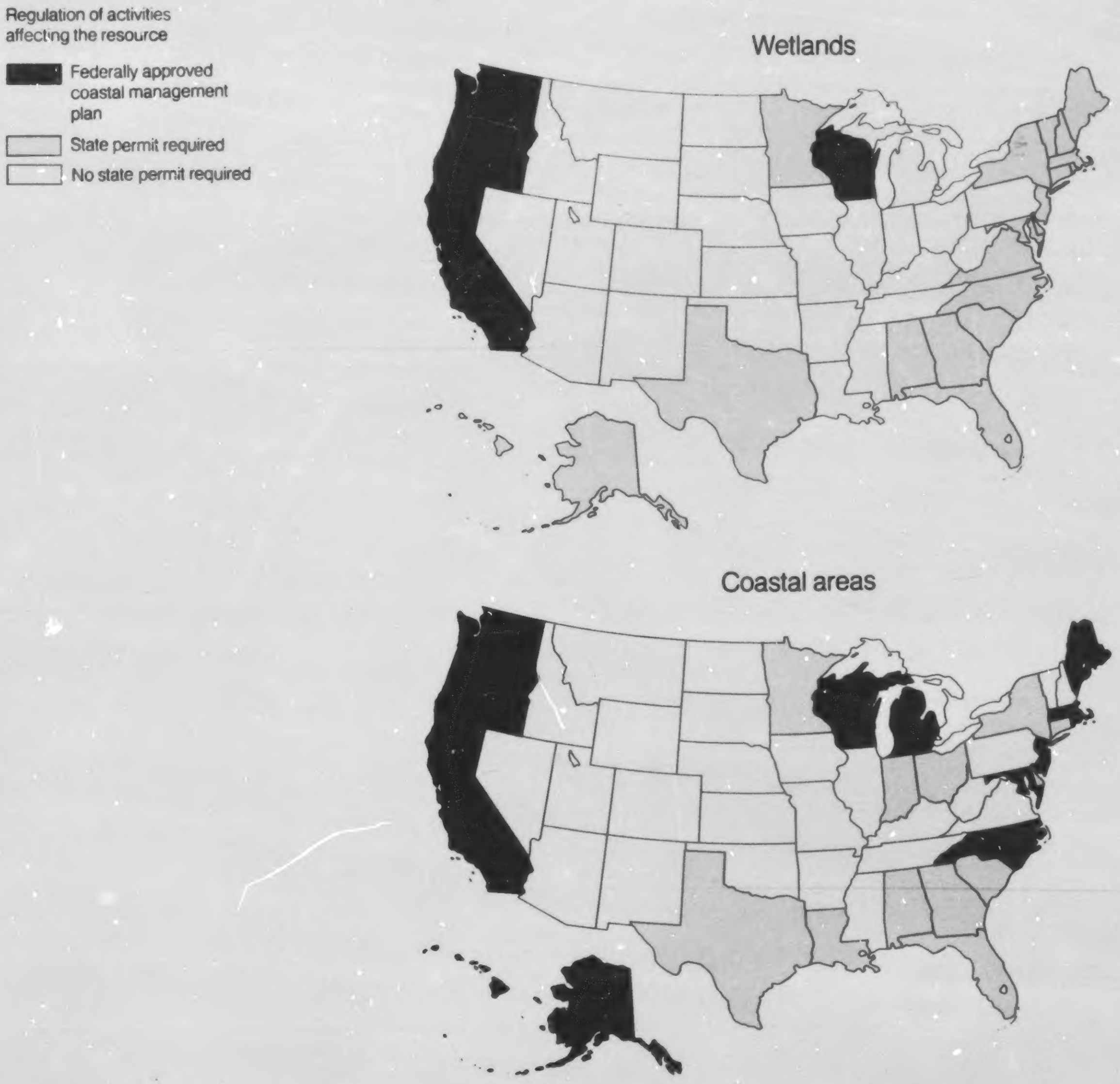
In Florida, wetlands are drained and filled for residential and agricultural uses, especially pasture land. Along the Mississippi and Louisiana coasts, they are dredged and filled for oil and gas pipelines as well as for industrial development and urban settlement. In the North Central States, primarily Minnesota and Wisconsin, wetlands are most often converted to cropland.

2-5

State programs protecting wetlands and coastal areas, 1978

Increasing numbers of States are developing legislation and regulatory procedures to protect wetlands and coastal areas.

Wetlands are also protected by Federal regulations and by Executive Orders. The two latest, issued in May 1977, require all Federal agencies to refrain from supporting construction in wetlands when there is a practical alternative.


Regulation of activities affecting the resource
■ Federally approved coastal management plan
▨ State permit required
☐ No state permit required
Wetlands
Coastal areas

Sources and Technical notes

2-1
Natural wetlands, 1954

Water atlas of the United States, Water Information Center, Inc. (Port Washington, N.Y., 1973), plate 74.

Wetlands of the United States, Samuel P. Shaw and C. Gordon Fredine, U.S. Fish and Wildlife Service (Washington, D.C., 1956), circ. 39, plate 21.

The map does not show approximately 11 million acres of wetlands not specifically delineated.

Data not available for Alaska and Hawaii.

The Fish and Wildlife Service, Office of Biological Services, is conducting the National Wetlands Inventory. National summary data are expected to be available in 1982.

2-2
Total wetland acreage, presettlement to 1971

Wetlands of the United States, Samuel P. Shaw and C. Gordon Fredine, U.S. Fish and Wildlife Service (Washington, D.C., 1956), circ. 39, pp. 6–7.

"Inland wetlands: Their ecological role and environmental status," William Niering and Richard Goodwin, *Bull. Ecol. Soc. Amer.* 55(2):4 (June 1974).

Data include 48 States only.

2-3
Wetland acreages, selected States, 1850–1975

Wetlands of the United States, Samuel P. Shaw and C. Gordon Fredine, U.S. Fish and Wildlife Service (Washington, D.C., 1956), circ. 39, p. 7.

Florida State Planning Office, Tallahassee, unpublished data.

Cooperative Gulf of Mexico estuarine inventory and study, Louisiana, National Oceanic and Atmospheric Administration and Louisiana Department of Wildlife and Fisheries (New Orleans, 1971), phase I, area description, and phase IV, biology, p. 10.

"Deterioration and restoration of coastal wetlands," S. M. Gagliano et al., reprinted from *Proceedings of 12th International Conference of Coastal Engineering*, Washington, D.C. (Jackson, Miss.: The Gulf Coast Association of Geological Societies, 1970), p. 7.

"Versatile wetlands—an endangered species," Peter Sullivan, *Conservation News* 41(5):20 (1976), p. 5.

Supplementary report on the coastal wetlands inventory of Delaware, U.S. Fish and Wildlife Service (Washington: USGPO, 1965).

"Search for wetlands," Kathi Jensen, *Delaware Conservationist* 19(16):2 (1965).

Cooperative Gulf of Mexico estuarine inventory and study, Mississippi, National Oceanic and Atmospheric Administration and Mississippi Marine Conservation Commission (Ocean Springs, Miss.: Gulf Coast Research Laboratory, 1973), pp. 16, 179, 180.

Long Island marine wetlands: Status, value, and preservation potentials, New York State Department of Environmental Conservation (Albany: Office of Planning Services, 1972), pp. 9–10.

2-4
Use of filled wetlands, Maine to Delaware, 1955–1964

Fish and man: Conflict in the Atlantic estuary, John Clark (Highlands, N.J.: American Littoral Society, 1967), spec. pub. 5, reprinted in *The economic and social importance of estuaries*, EPA (Washington: USGPO, 1971), p. E-7.

2-5
State programs protecting wetlands and coastal areas, 1978

National Wetlands Newsletter, Environmental Law Institute, v. 1, n. 3 (February 1979).

Strengthening State wetlands regulations, U.S. Fish and Wildlife Service (Washington: USGPO, 1979).

"Computer-aided environmental legislative data system," U.S. Army Corps of Engineers, Construction Engineering Research Laboratory (accessed April–May 1979).

Floodplain management (Executive Order 11988) and *Protection of wetlands* (Executive Order 11990), both issued in May 1977, directly affect coastal and riverine wetlands by prohibiting Federal agencies from needlessly damaging or destroying floodplains and wetlands.

Wild areas

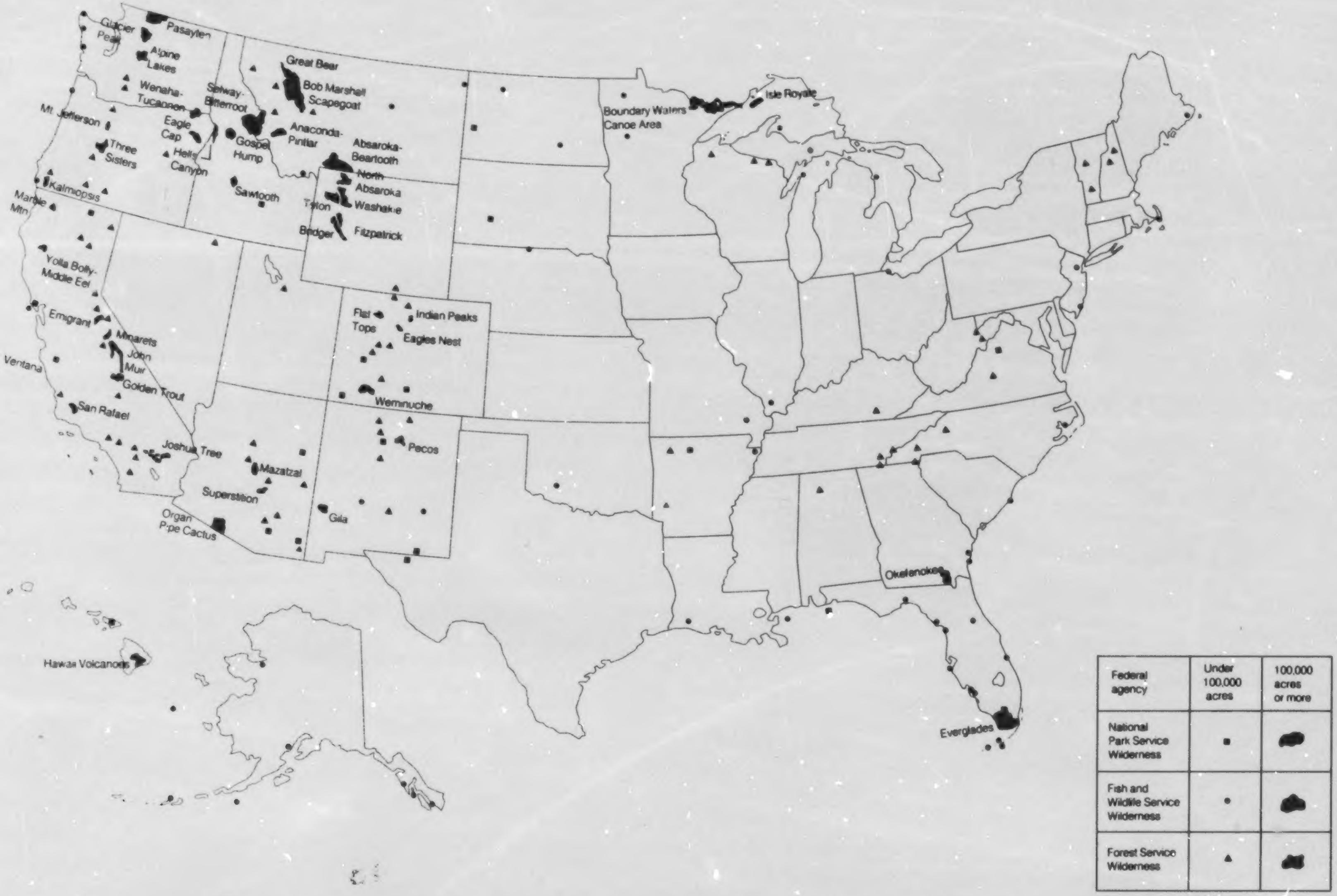
Wilderness has been disappearing since the Europeans settled on the Atlantic coast in the 17th century. New settlements, industries, roads, timber cutting, agriculture, and other human activities continue to encroach on the remaining large tracts of untouched land.

But large areas of wilderness are being set aside for protection against any form of development by the National Wilderness Preservation System. This Federal program, officially begun in 1964, protects large tracts of Federal land from further development. Its aim is to preserve the solitude and natural beauty of untouched wilderness and to ensure that areas remain where only natural changes take place.

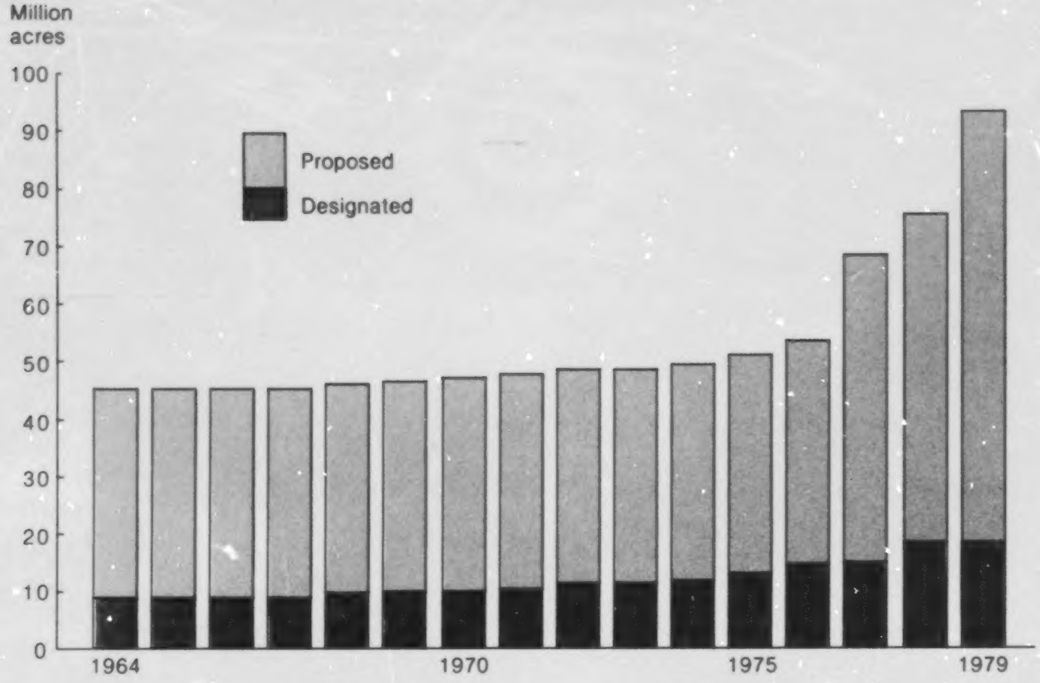
2-6
National Wilderness Preservation System, 1978

Wilderness Preservation Areas are natural areas of at least 5,000 acres or are large enough to make preservation feasible. They are protected from all forms of human development. No roads or structures may be built, but some visitor services are provided outside their boundaries, and visits within an area may be controlled if excessive use causes environmental problems. Camping, hiking, backpacking, nature walks, horseback riding, cross country skiing, and other nonmechanical recreational activities are permitted.

Designation as a Wilderness Area usually leads to increased use. The Forest Service counted 8 million visitors to its administered Wilderness and Primitive Lands in 1977, almost double the number 10 years earlier on about the same amount of land. In these areas, recreation is secondary to preserving the land in its natural state.


Pasayten
Glacier Peak
Alpine Lakes
Wenaha-Tucannon
Mt. Jefferson
Eagle Cap
Hells Canyon
Three Sisters
Kalmiopsis
Marble Mtn
Selway-Bitterroot
Gospel Hump
Sawtooth
Great Bear
Bob Marshall
Scapegoat
Anaconda-Pintlar
Absaroka-Beartooth
North Absaroka
Washakie
Teton
Bridger
Fitzpatrick
Yolla Bolly-Middle Eel
Emigrant
Minarets
John Muir
Golden Trout
Ventana
San Rafael
Joshua Tree
Flat Tops
Indian Peaks
Eagles Nest
Weminuche
Pecos
Mazatzal
Superstition
Gila
Organ Pipe Cactus
Hawaii Volcanoes
Boundary Waters Canoe Area
Isle Royale
Okefenokee
Everglades
Federal agency
Under 100,000 acres
100,000 acres or more
National Park Service Wilderness ■
Fish and Wildlife Service Wilderness ●
Forest Service Wilderness ▲

2-7
Designated and proposed wilderness areas, 1964–1979



The system began in 1964 with 9.2 million acres. By February 1979, there were 19.0 million acres in 190 Federally designated areas in 40 States.

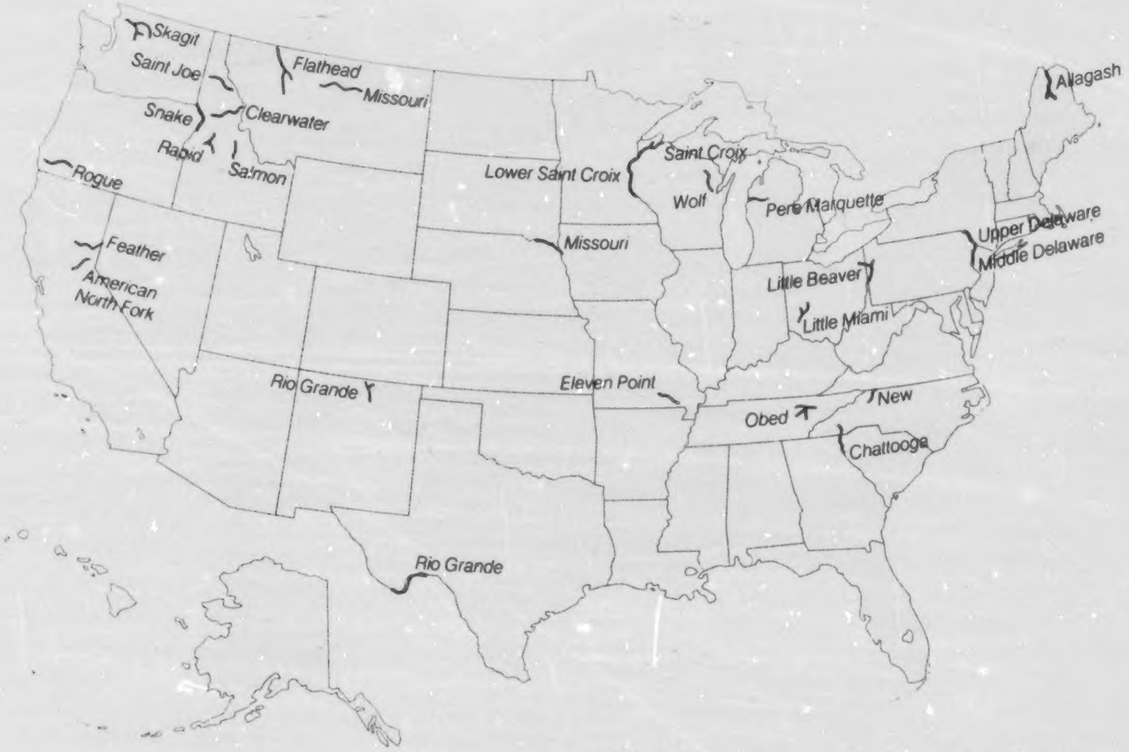
An additional 74.7 million acres have been proposed for inclusion, including 42.0 million in Alaska. Proposed areas are protected by Federal land management agencies until their suitability is finally determined by Congress.

☐ Of the 19.0 million acres, 15.3 million, representing 80.2%, are administered by the U.S. Forest Service; 15.6% by the National Park Service; 4.1% by the Fish and Wildlife Service; and 0.1% by the Bureau of Land Management.

In addition to the National Wilderness Preservation System, which contains only Federal land, 25 States now maintain areas in wilderness or as nature preserves. Many more areas, with varying degrees of protection, are privately owned.

2-8

National Wild and Scenic Rivers, 1978


Skagit
Saint Joe
Flathead
Missouri
Snake
Clearwater
Rapid
Salmon
Rogue
Feather
American North Fork
Lower Saint Croix
Saint Croix
Wolf
Pere Marquette
Missouri
Allagash
Upper Delaware
Middle Delaware
Little Beaver
Little Miami
Rio Grande
Eleven Point
Obed
New
Chattooga
Rio Grande

Since 1968, rivers have been protected under the National Wild and Scenic Rivers System. Twenty-five river segments totaling 2,317 miles have been designated as units of the system, and 75 are being considered for inclusion. Like proposed wilderness areas, proposed river areas are protected while under study.

The longest river segment in the system is the Flathead (219 miles) in Montana. The shortest is the Rapid (24 miles) in Idaho.

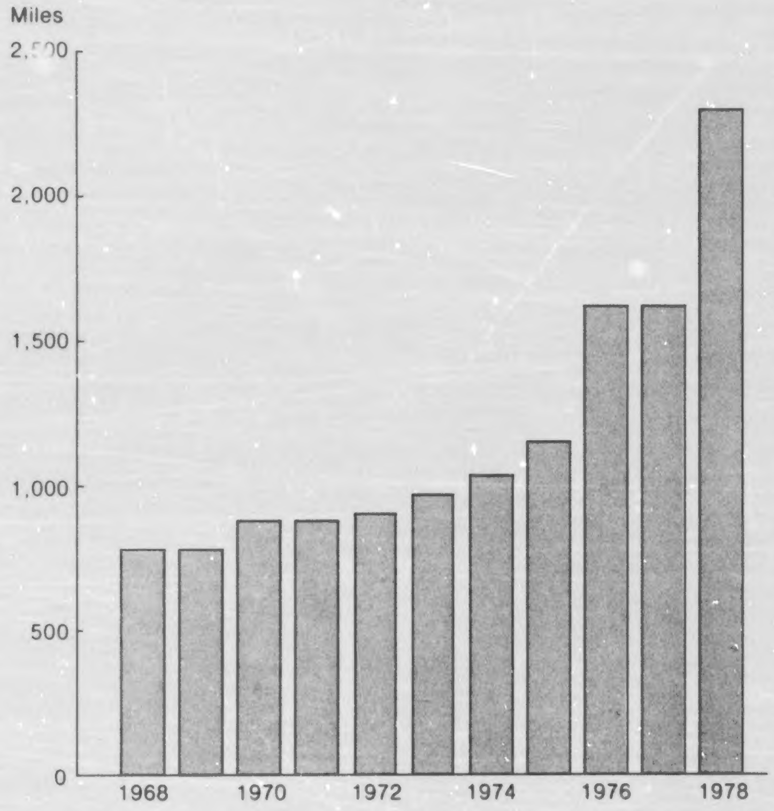
To be eligible, a river or river segment must be free flowing, have high quality water, and possess one or more outstanding scenic, recreational, geologic, fish and wildlife, historic, cultural, or similar values.

Rivers in the system are classified in three ways: Wild rivers (841 miles) are free from impoundments, with watersheds or shorelines essentially primitive and with unpolluted water, and are generally inaccessible except by trail. Scenic rivers (774 miles) are free of impoundments, with watersheds or shorelines largely primitive and shorelines largely undeveloped, but they may be accessible by road or railroad. Recreational rivers (702 miles) have undergone some impoundment or diversion in the past, are accessible by road or railroad, and may have some development along their banks.

☐ The National Wild and Scenic Rivers System is administered by the Departments of the Interior and Agriculture in cooperation with State agencies.

2-9

The National Wild and Scenic Rivers System, 1968–1978



In 1978, 659 river miles were designated Wild and Scenic—more than at any one time since the beginning of the program. Newly designated were the Skagit in Washington, the upper Delaware in New York and Pennsylvania, and a 191-mile stretch of the Rio Grande in Texas.

States also designate wild rivers. State wild rivers may be added to the national system upon application by the Governor to the Secretary of the Interior. So far, at least 23 States have passed laws to protect their rivers. Particularly strong are the preservation programs in Minnesota, California, and Oregon.

Sources and technical notes

2-6
National Wilderness Preservation System, 1978

USDA Forest Service.

BLM lands were first admitted to the system in 1979 and are not shown on the map.

2-7
Designated and proposed Wilderness Areas, 1964–1979

1964–1976: USDA Forest Service, National Wilderness Monitoring System, computer printout, August 1, 1977.

1977–1979: "Wilderness fact sheet," USDA Forest Service, Recreation Management Staff, February 15, 1979. Unpublished data from USDA Forest Service; National Park Service; U.S. Fish and Wildlife Service; Bureau of Land Management.

In addition to the acreage shown, the 1976 BLM Organic Act includes approximately 120 million acres which are under consideration for wilderness designation.

2-8
National Wild and Scenic Rivers, 1978

U.S. Department of the Interior, Heritage Conservation and Recreation Service.

2-9
The National Wild and Scenic Rivers System, 1968–1978

Environmental quality—1976, Council on Environmental Quality (Washington: USGPO, 1976), p. 96.

U.S. Department of the Interior, Heritage Conservation and Recreation Service, unpublished data.

Parks

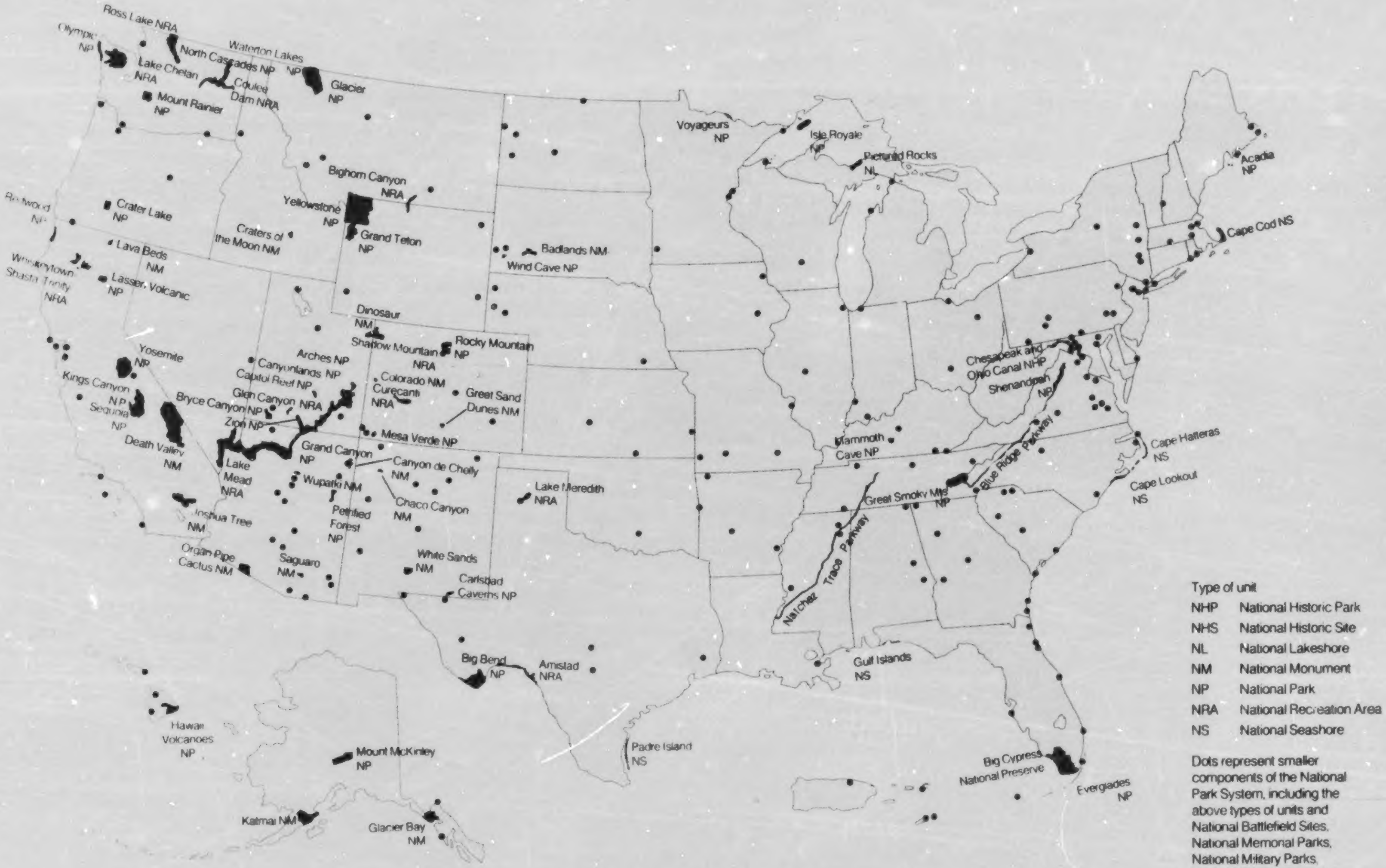
The parks of the United States are numerous and varied. They include rivers, lakes, forests, beaches and seashores, trails, parkways, urban places, monuments, and large areas of outstanding natural value. In varying degrees, parks are created to protect important natural areas and valuable cultural sites.

Although protected, parks are not immune to deterioration and destruction. Stresses on parklands from heavy and sometimes uncontrolled visitor use are compounded by adjacent development and incompatible land uses.

2-10

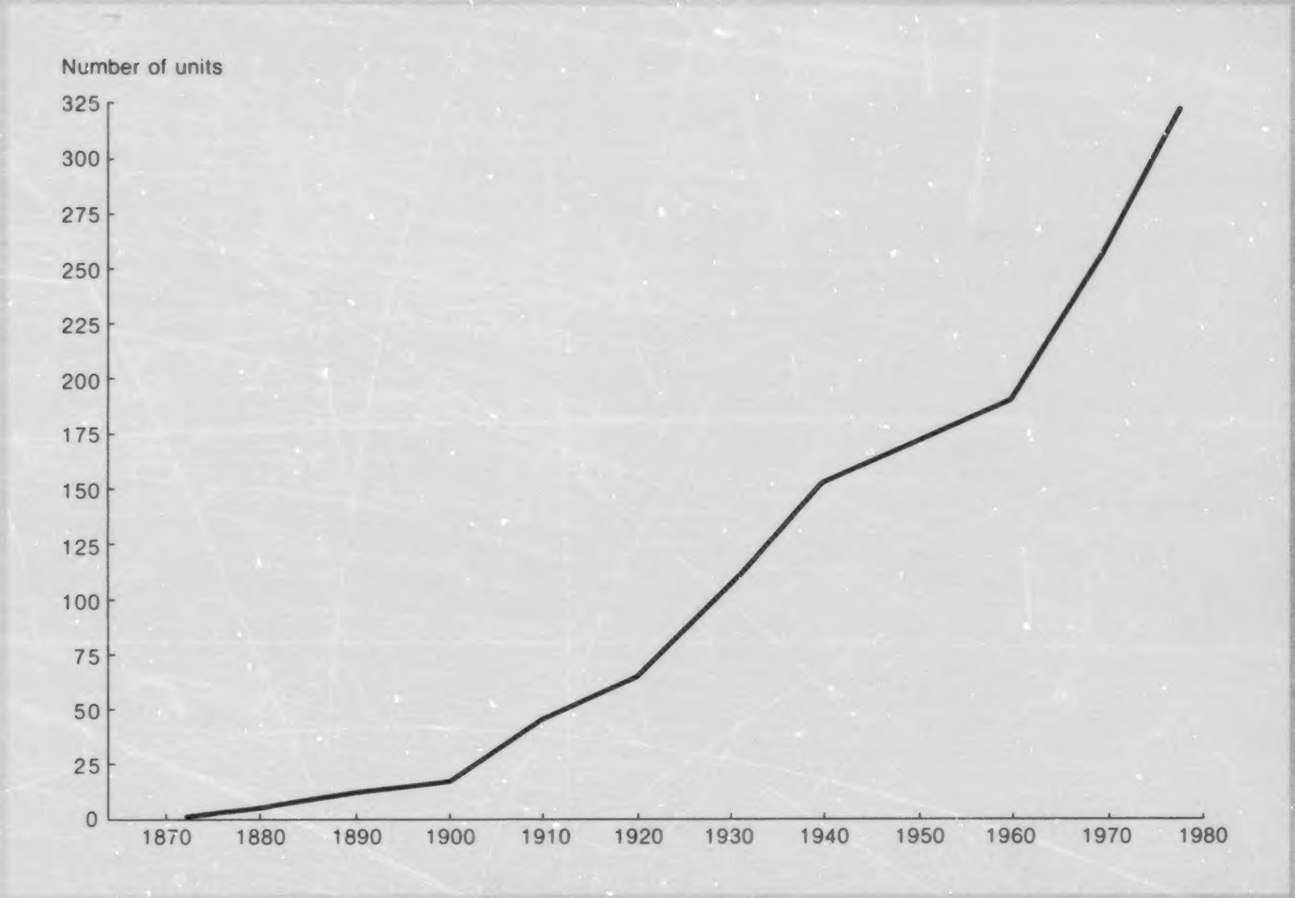
The National Park System, 1979

In 1978, the National Park System included 322 units: 88 natural areas (parks, monuments, natural preserves), 181 historical areas (battlefields, cemeteries, monuments), and 53 recreational areas (parkways, rivers, seashores). They are located in 49 States, Puerto Rico, and the Virgin Islands. Only Vermont does not have a National Park.


Ross Lake NRA
Olympic NP
Lake Chelan NRA
North Cascades NP
Waterton Lakes NP
Coulee Dam NRA
Glacier NP
Mount Rainier NP
Bighorn Canyon NRA
Yellowstone NP
Redwood NP
Crater Lake NP
Craters of the Moon NM
Grand Teton NP
Lava Beds NM
Whiskeytown Shasta Trinity NRA
Lassen Volcanic NP
Badlands NM
Wind Cave NP
Dinosaur NM
Shadow Mountain NRA
Rocky Mountain NP
Yosemite NP
Arches NP
Canyonlands NP
Capitol Reef NP
Colorado NM
Curecanti NRA
Great Sand Dunes NM
Kings Canyon NP
Sequoia NP
Bryce Canyon NP
Glen Canyon NRA
Zion NP
Mesa Verde NP
Death Valley NM
Lake Mead NRA
Grand Canyon NP
Canyon de Chelly NM
Wupatki NM
Chaco Canyon NM
Lake Meredith NRA
Petrified Forest NP
Joshua Tree NM
Organ Pipe Cactus NM
Saguaro NM
White Sands NM
Carlsbad Caverns NP
Big Bend NP
Amistad NRA
Padre Island NS
Hawaii Volcanoes NP
Mount McKinley NP
Katmai NM
Glacier Bay NM
Voyageurs NP
Isle Royale NP
Pictured Rocks NL
Acadia NP
Cape Cod NS
Chesapeake and Ohio Canal NHP
Shenandoah NP
Mammoth Cave NP
Cape Hatteras NS
Blue Ridge Parkway
Great Smoky Mts NP
Cape Lookout NS
Natchez Trace Parkway
Gulf Islands NS
Big Cypress National Preserve
Everglades NP
Type of unit
NHP National Historic Park
NHS National Historic Site
NL National Lakeshore
NM National Monument
NP National Park
NRA National Recreation Area
NS National Seashore

Dots represent smaller components of the National Park System, including the above types of units and National Battlefield Sites, National Memorial Parks, National Military Parks, National Scenic Riverways, and National Scenic Parkways.

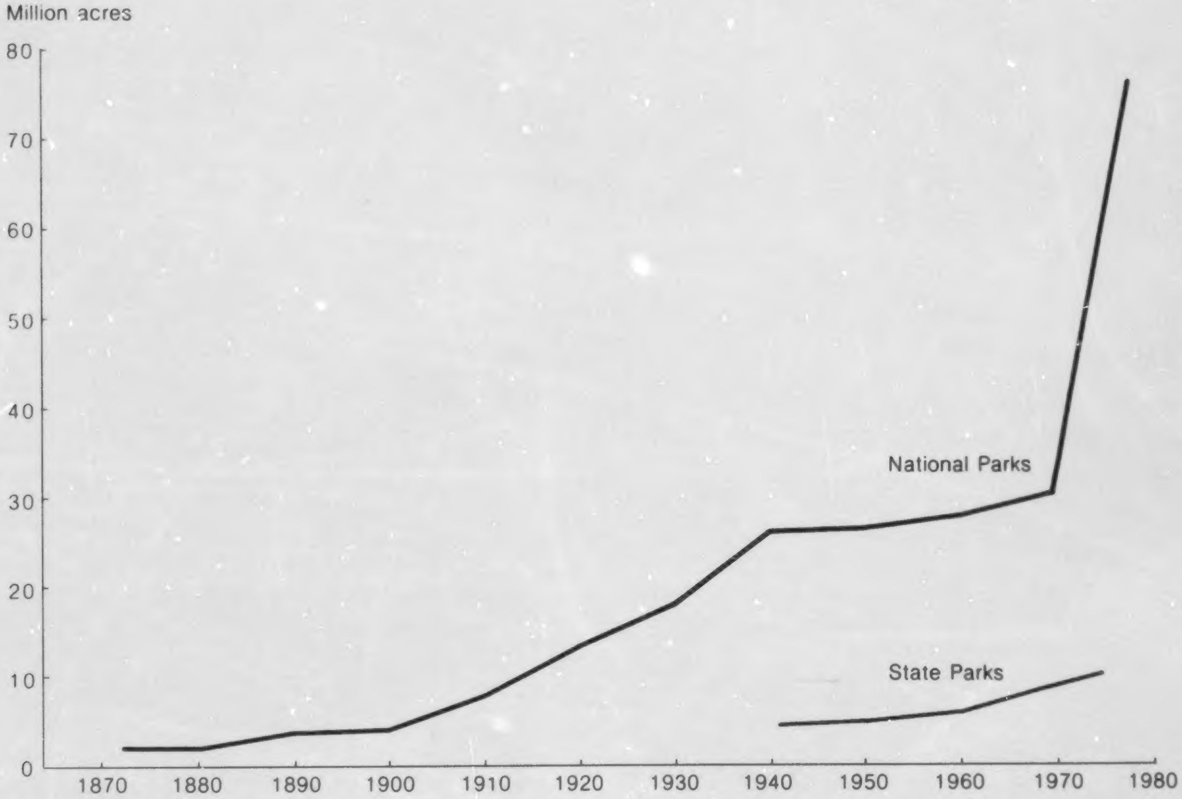
2-11
National Park Service units, 1872–1978



For an area to become part of the National Park System, it must be of national significance (natural or historic), and it must be able to be administered and protected by the National Park Service. An area is included in the National Park System only by an Act of Congress or Executive Order of the President.

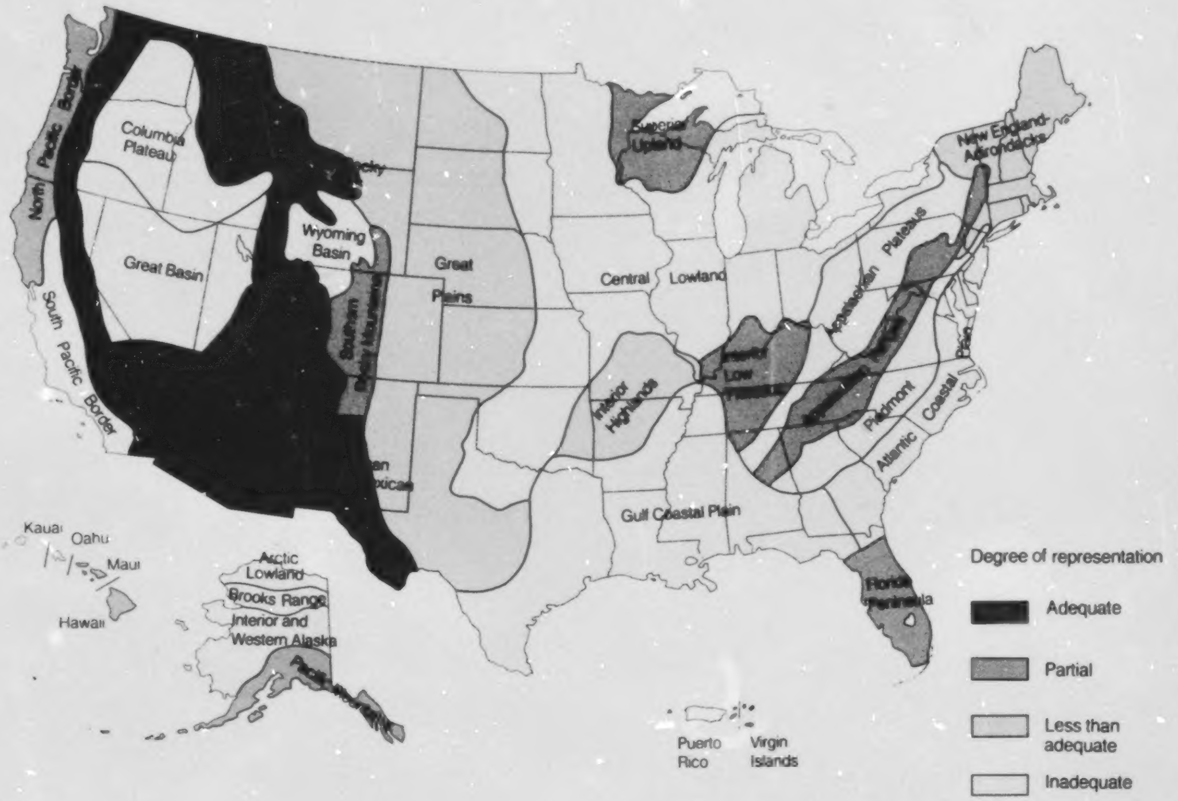
The number of units in the National Park System has been growing rapidly. Since 1960, more than 130 areas have been added—65 historical areas (0.2 million acres), 40 recreational areas (4.8 million acres), and 27 natural areas (43.0 million acres).

2-12
National and State Park acreages, 1872–1978



In 1978, 44 million acres were added to the National Park System, more than doubling its size. Most of the acreage was in Alaska. The other areas were generally small.

2-13
Representation of natural regions in the National Park System, 1970

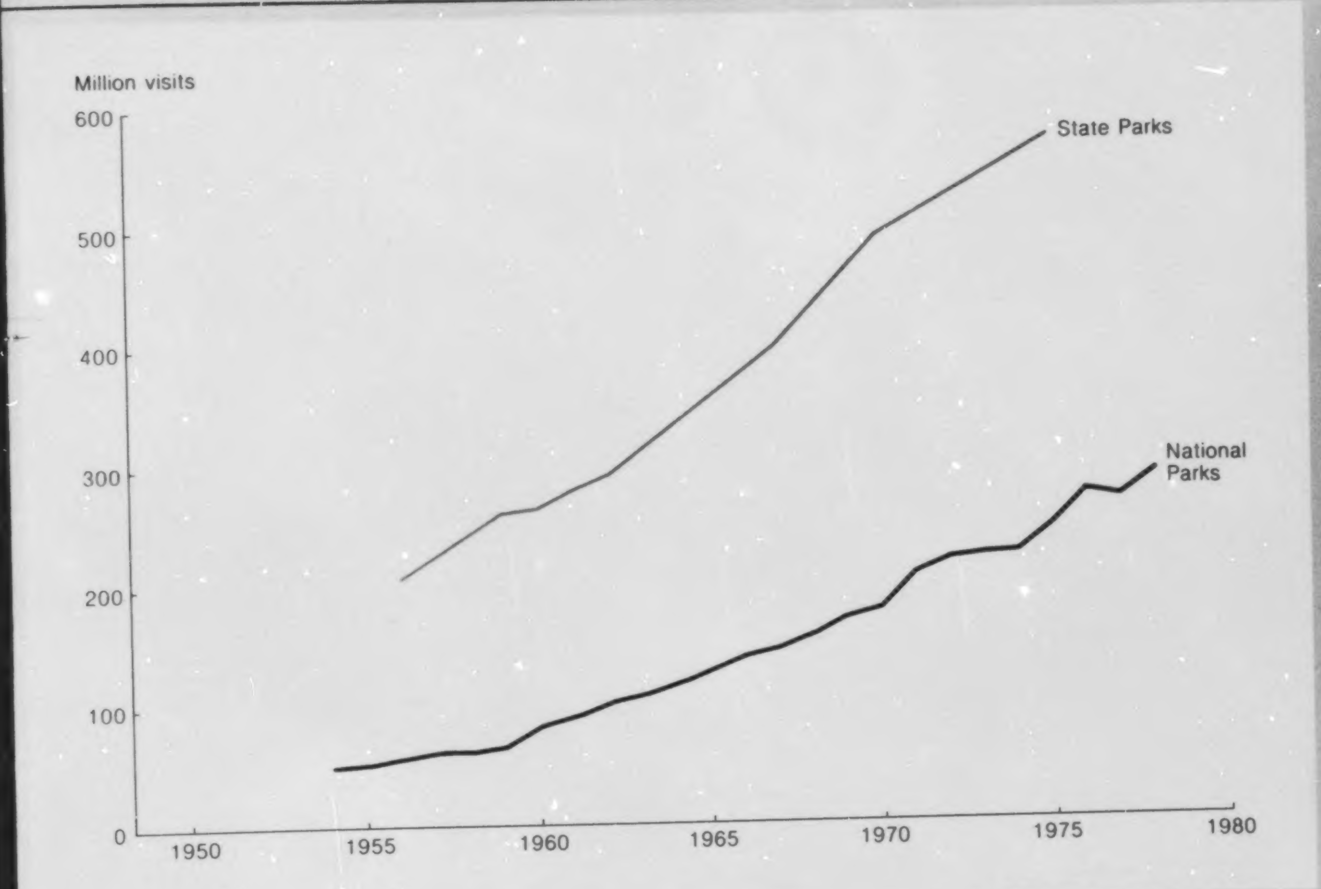

Columbia Plateau
Great Basin
North Pacific Border
South Pacific Border
Rocky
Wyoming Basin
Southern Rocky Mountains
Great Plains
an
xican
Superior Upland
Central Lowland
New England-Adirondacks
Appalachian Plateaus
Interior Low Plateaus
Interior Highlands
Piedmont
Atlantic Coastal Plain
Gulf Coastal Plain
Florida Peninsula
Kauai
Oahu
Maui
Hawaii
Arctic Lowland
Brooks Range
Interior and Western Alaska
Pacific Mountain
Puerto Rico
Virgin Islands
Degree of representation
Adequate
Partial
Less than adequate
Inadequate

Of the major ecological and regional land types in the United States, about half are well represented in the National Park System. They include the seashores and forests of the Northwest, the deserts of the West, and the geological formations of the Southwest.

Natural regions that are not well represented and whose protection is in doubt are the coastal plain of the Atlantic, its islands and estuaries; the Central Lowlands and their tall grass prairies; the Great Basin of the West, with its islands of alpine vegetation and its cold desert; and the Columbia Plateau, with its deserts in eastern Oregon and Washington.

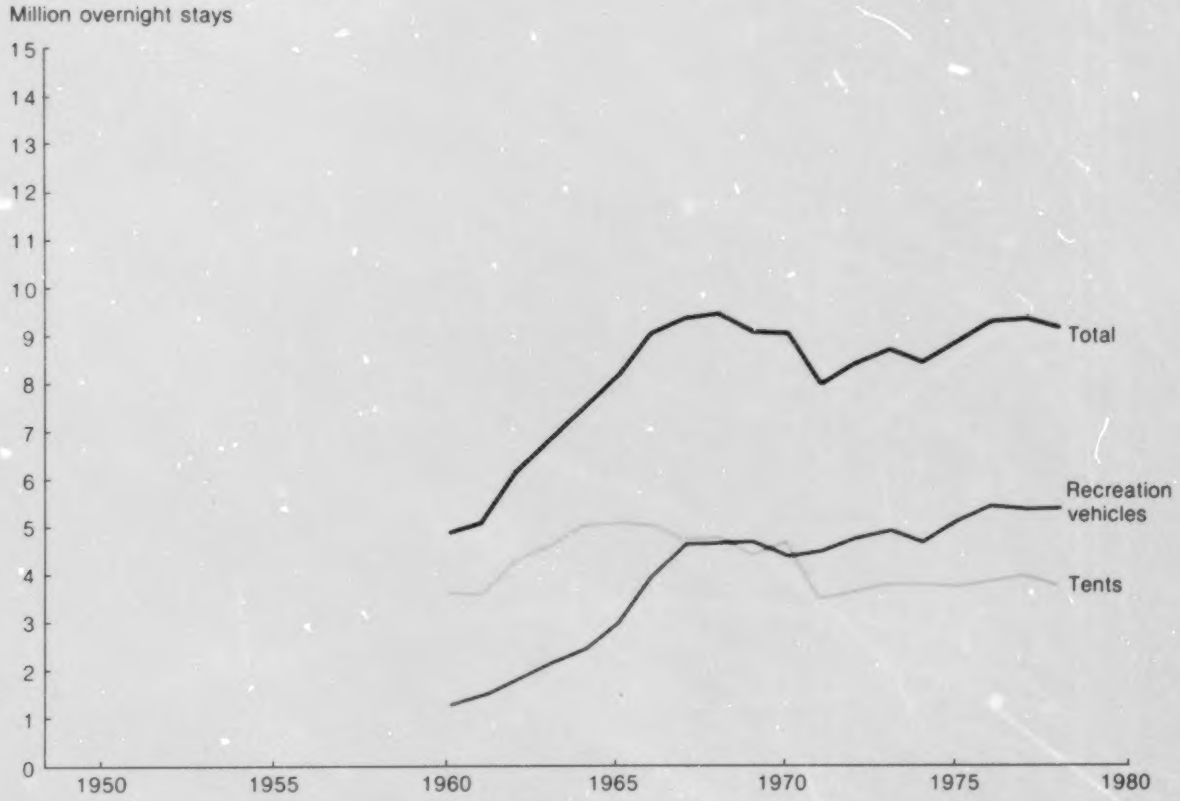
☐ The degree of representation is based on the judgment of National Park Service analysts. Geologic and ecological features in each region were given scores based on their quantity, quality, diversity, and uniqueness. Scores for all features were added and a total percentage calculated. Percentages were the ratio of features in the National Park System to natural phenomena within a region. The range of 0–25% is equivalent to inadequate representation; 26–50%, less than adequate; 51–75%, partial; and 76–100%, adequate.

2-14
Visits to National and State Parks, 1954–1978



Park visits continue to increase in both National and State Parks. There are now roughly four visits to State and National park land per person per year.

2-15
Overnight stays in National Park Service-operated campgrounds, 1960-1978

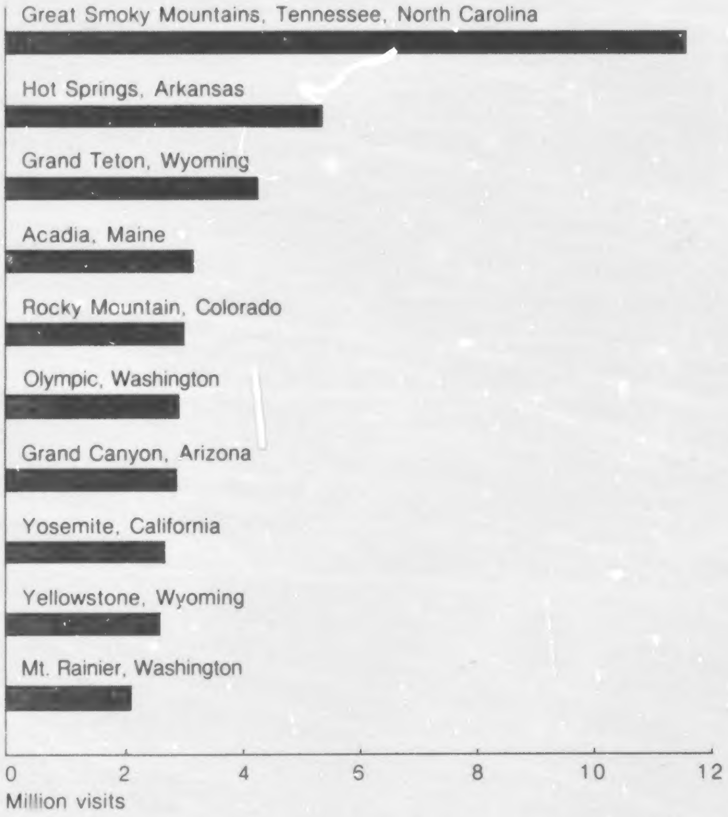


The number of overnight stays in National Park campgrounds has increased since 1960 largely because of the popularity of recreational vehicles.

☐ Overnight stays include family campground camping only and exclude non-campground camping, which totaled 8.5 million in 1978. Excluded are commercial camping in cabins and lodges, nonrecreational stays by concessioner employees and business visitors, and other camping, such as backcountry and boat camping.

2-16

The 10 most popular National Parks, 1978



The largest, oldest, and most famous parks are in the West. Two of the most heavily visited parks, however, are in the East: Great Smoky Mountains National Park and Acadia National Park.

☐ Includes National Parks only. Excludes National Seashores, Parkways, Recreation Areas, Historic Sites, Historical Parks, etc.

Sources and technical notes

2-10

The National Park System, 1979

National Park Service.

2-11

National Park Service units, 1872-1978

1872–1976: *Index of the National Park System and affiliated areas as of January 1, 1975,* National Park Service (Washington: USGPO, 1975); photocopy of updated addenda to the index, October 22, 1976.

1977: *National Park statistical abstract 1977,* National Park Service (Washington: USGPO, 1978), table 1, p. 1.

1978: Photocopy of updated addenda to the 1977 index, February 1979.

2-12

National and State Park acreages, 1872-1978

National: See 2-11.

State, 1941–1975: *State park statistics—1970,* National Recreation and Park Association (Arlington, Va., 1971), p. 9; *Statistical abstract of the United States: 1976* (Washington: USGPO, 1976), table 355, p. 216; *State park statistics—1975* (Arlington, Va., 1977), p. 28.

2-13

Representation of natural regions in the National Park System, 1970

Part two of the National Park System plan, natural history, National Park Service (Washington: USGPO, 1972), figs. 1a, 3, pp. 6–7, 12–13, based on "Physiographic divisions of the United States," N. M. Fenneman, *Annals of the Association of American Geographers,* v. 18 (3rd ed., 1928).

2-14

Visits to National and State parks, 1954-1978

National Parks, 1945–1975: *Public use of the National Parks: A statistical report, 1954–1964,* National Park Service (Washington: USGPO, 1966), p. 4; *Public use of the National Parks: A statistical report, 1960–1970* (USGPO, 1971), p. 5; *Public use of the National Parks, December 1972* (USGPO, 1972), p. 9; *Public use of the National Park System, calendar year report 1973* (USGPO, 1974), p. 6; *Public use of the National Park System, calendar year report 1975* (USGPO, 1976), p. 23. 1976: *National Park statistical abstract, 1977* (USGPO, 1978), table 2, p. 2. 1977–1978: *National Park statistical abstract, 1978* (USGPO, 1979), table 2, p. 2.

State Parks, 1956–1975: *State park statistics, 1970,* National Park and Recreation Association (Arlington, Va., 1971), p. 9; *State park statistics, 1975* (Arlington, Va., 1977), p. 27.

2-15

Overnight stays in National Park Service-operated campgrounds, 1960-1978

National Park statistical abstracts, 1978, National Park Service (Washington: USGPO, 1979), table 3, p. 2.

2-16

The 10 most popular National Parks, 1978

National Park statistical abstract, 1978, National Park Service (Washington: USGPO, 1979), table 4, pp. 7–17.

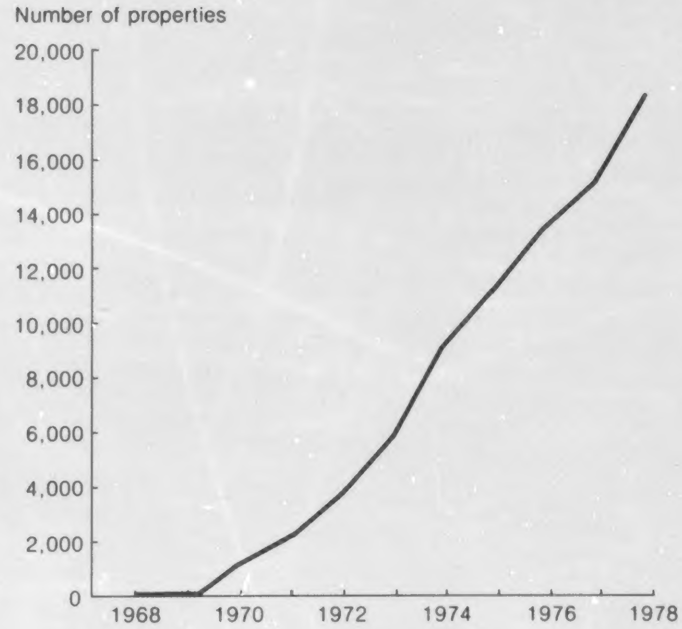
Historic places

Unlike the European nations, the United States has made a late start in protecting its historic heritage. The Historic Sites Act of 1935 gave the Federal Government authority to conduct a survey of sites of exceptional historical value. With passage of the National Historic Preservation Act in 1966, places and areas of historic interest were systematically identified and listed on a National Register. But registration does not guarantee protection. It brings historically important properties to public attention, thereby increasing the likelihood that they will be preserved or restored and used. The act also authorizes Federal grant money and tax benefits for rehabilitation of registered properties.

In addition to the National Register of Historic Places, the Federal Government maintains the Historic American Buildings Survey (a program to preserve records of important examples of architecture), the Historic American Engineering Record (established in 1969 to document historic engineering, industrial, and technological works throughout the country), and other preservation programs. Most preservation and conservation efforts depend on State and local government and require private funding.

2-17

Properties on the National Register of Historic Places, 1968–1978

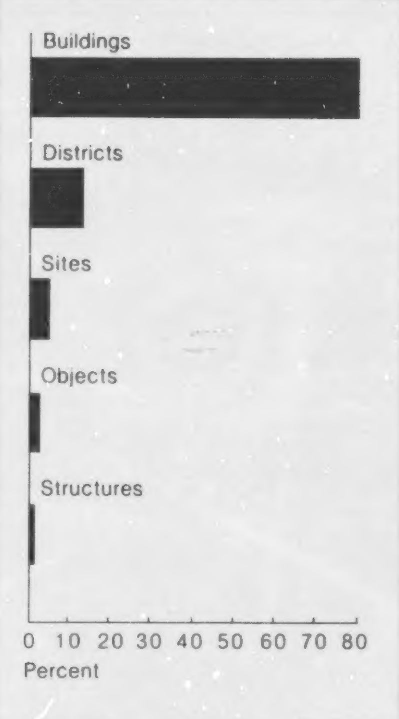


At the end of 1978, more than 18,300 historic places were listed in the National Register. The number is expected to reach 67,000 by the mid-1980s.

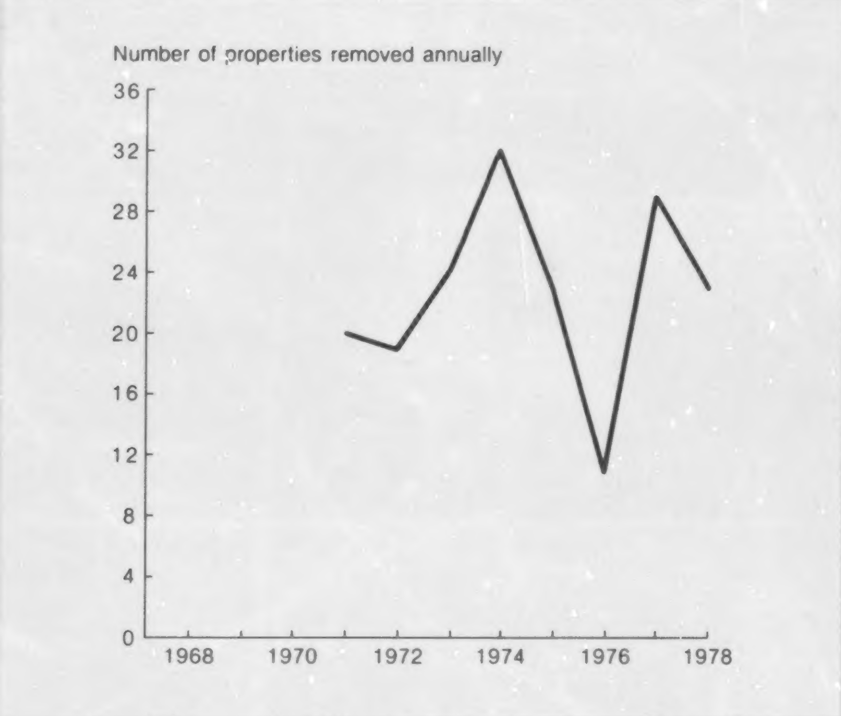
For a property to be nominated for the National Register, it must meet one of four criteria: It must be associated with events that have made a significant contribution to history. It must be associated with the lives of important persons in history. It must embody distinctive characteristics of type, period, or method of construction, represent the work of a master, or possess high artistic value. Or it must yield information important in prehistory or history.

Almost all nominations come from State historic preservation officers. Properties are placed on the register by approval of the Secretary of the Interior. The number of nominations is a function of the financial resources available for preparing the necessary documentation and background information. About 97% of properties nominated are listed in the register.

2-18
Properties on the National Register of Historic Places, by type, 1978



2-19
Properties removed from the National Register of Historic Places, 1971-1978



By far the largest number of listings on the register are buildings. They include barns, houses, and industrial and commercial buildings. Examples are the Laurel Mill in Gupton, North Carolina; the Wells Fargo and Company Express Building in Silver Reef, Utah; the Bradbury Building in Los Angeles; and the Starret House in Port Townsend, Washington.

The most significant increase in recent designations has been historic districts, which comprised about 13% of the listings in 1978. A district is a geographically definable area, urban or rural, possessing a significant concentration of sites, buildings, structures, or objects united by past events or aesthetic values. The average district contains 16 buildings and occupies 50 acres of land. Examples include the Mexican War Street District in Pittsburgh; the Annapolis Historic District in Maryland; Le Vieux Carre in New Orleans; and Green Springs, Virginia, a 14,000-acre area of 18th and 19th century farms.

Sites include archeological sites, battlefields, etc. Objects include trains, ships, statues, etc. Structures include bridges, windmills, aqueducts, etc.

Despite listing on the National Register, properties are lost each year. By the end of 1978, 212 properties had been removed from the register. Most losses result from demolition, usually for public or private redevelopment; others are from wind, fire, and other natural causes.

It has been estimated that during a 10-year period about 17% of all unprotected historically valuable structures have been lost. About 3% of the structures listed on the National Register have been lost during a similar period.

Sources and technical notes

2-17
Properties on the National Register of Historic Places, 1968-1978

U.S. Department of the Interior, Heritage Conservation and Recreation Service, National Register of Historic Places, unpublished data.

Includes National Historic Landmarks.

2-18
Properties on the National Register of Historic Places, by type, 1978

See 2-17.

A district may include up to 10,000 individual buildings or properties.

2-19
Properties removed from the National Register of Historic Places, 1971-1978

See 2-17.

Excludes 22 properties removed from the register prior to 1971 and 9 properties removed with no date indicating time of removal.

71

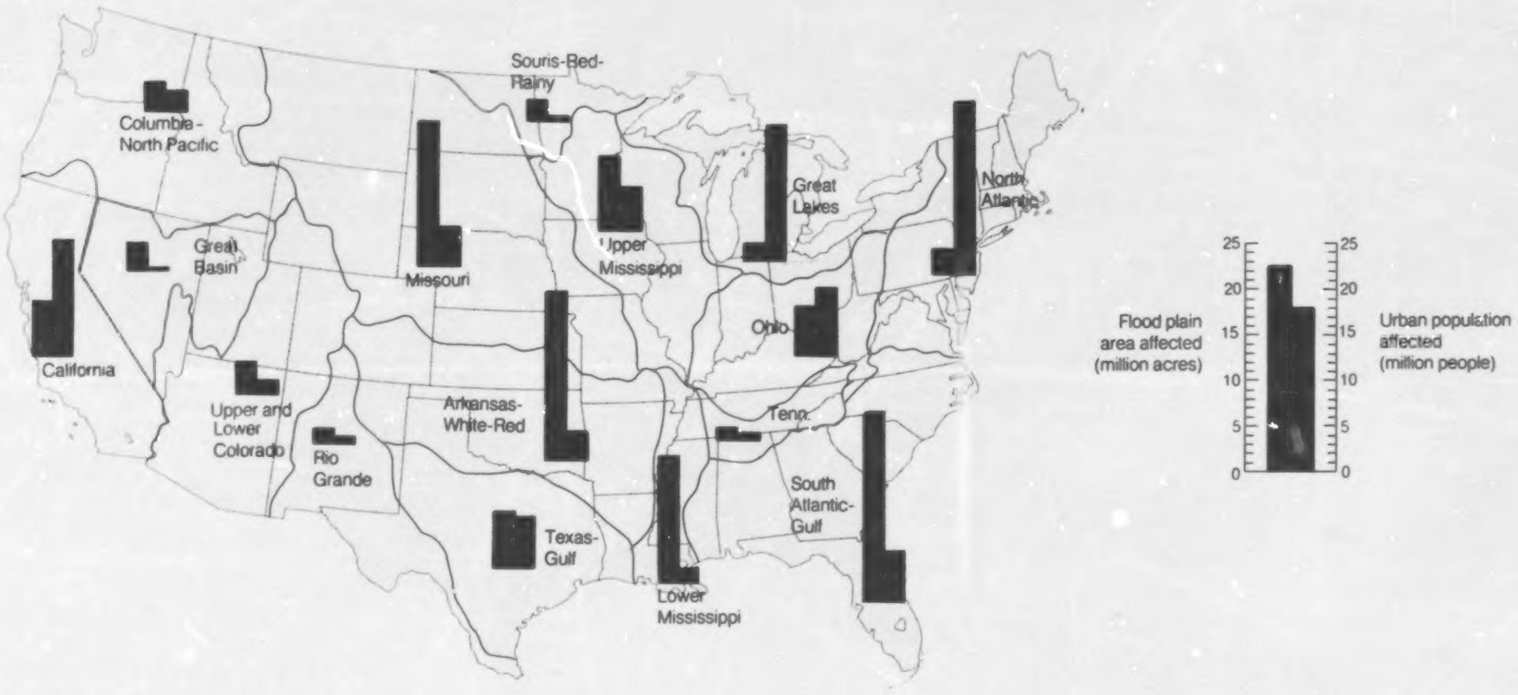
72

Risk zones

All areas of the United States are at risk from natural disasters of one kind or another. Hurricanes hit the Atlantic and Gulf coast States. Earthquakes are a potential danger in the West. Tornadoes and windstorms reach across the Midwest and the Plains. Floods occur in all major river basins.

There are a number of ways to reduce loss of life and property from these disasters: modifying the event (hurricane seeding to reduce wind velocity); modifying susceptibility or exposure to the event (land use adjustment and warning/evacuation); and modifying the impact of the event after it happens (social insurance and disaster assistance). All three approaches are used, but more attention is now being given to modifying land uses to reduce the probability of major catastrophe.

2-20
Urban population and lands affected by stream flooding, by Water Resources Region, 1967


Columbia-North Pacific
Souris-Red-Rainy
Great Lakes
North Atlantic
California
Great Basin
Missouri
Upper Mississippi
Ohio
Upper and Lower Colorado
Rio Grande
Arkansas-White-Red
Tenn.
South Atlantic-Gulf
Texas-Gulf
Lower Mississippi
Flood plain area affected (million acres)
Urban population affected (million people)
25
20
15
10
5
0

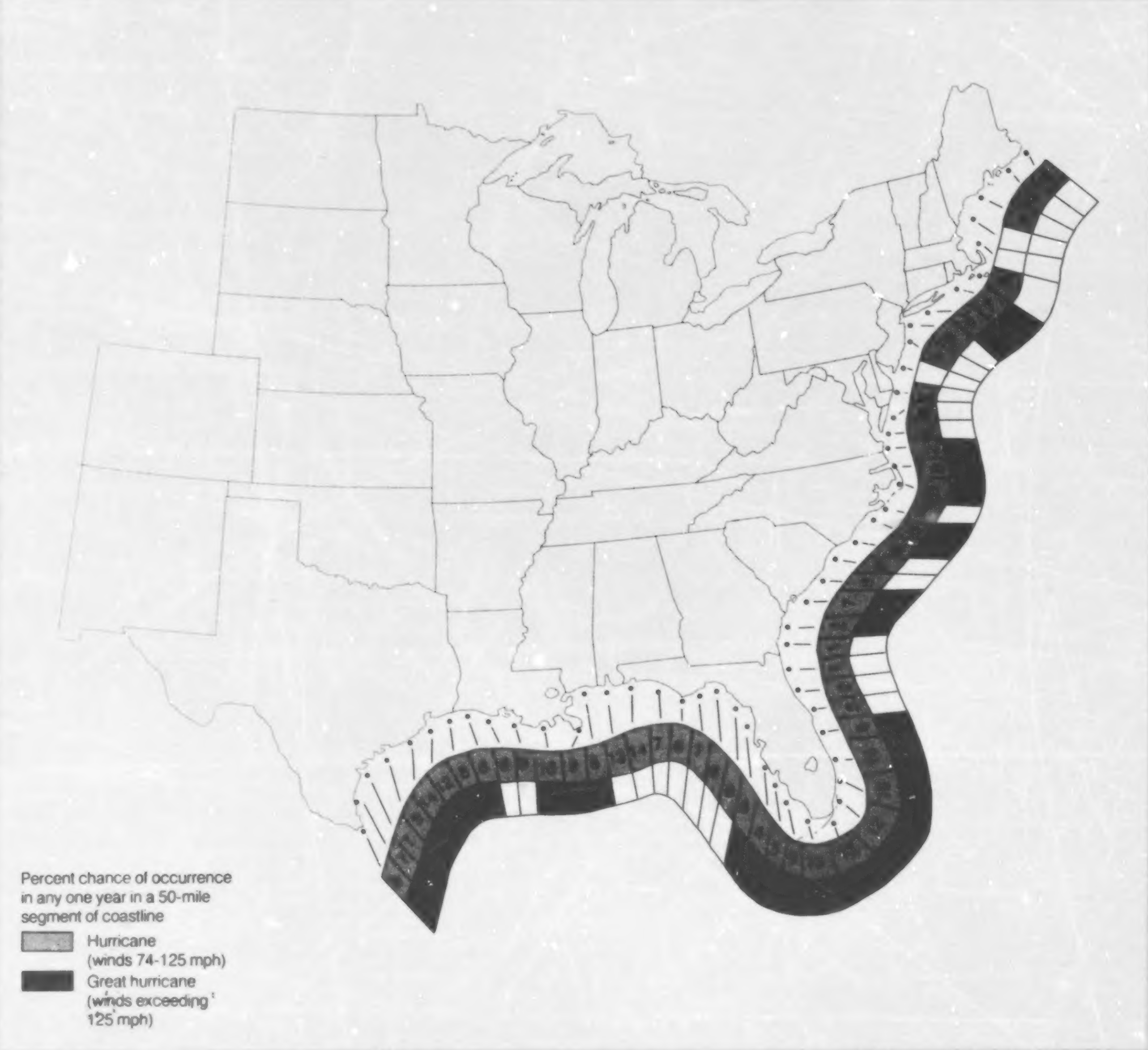
Floods are the most common and widespread geophysical hazard. Flooding affects major population centers in the Northeast, in the Ohio Basin, on the Great Lakes, and in California.

Some 100 million people are affected by stream flooding.

More than 15,000 communities and recreational areas have been identified as flash flood prone, and they are located in all but a few counties. Some 3,000 of these flood prone areas are at high risk in terms of potential death and property damage. Only 650 of them have flood warning systems to reduce the damage of flash floods.

Despite the dangers, the number of people building on flood plains continues to rise and so does the threat to life and property.

2-21
Hurricane risk along the Gulf and Atlantic coasts


Percent chance of occurrence in any one year in a 50-mile segment of coastline
▨ Hurricane (winds 74-125 mph)
■ Great hurricane (winds exceeding 125 mph)

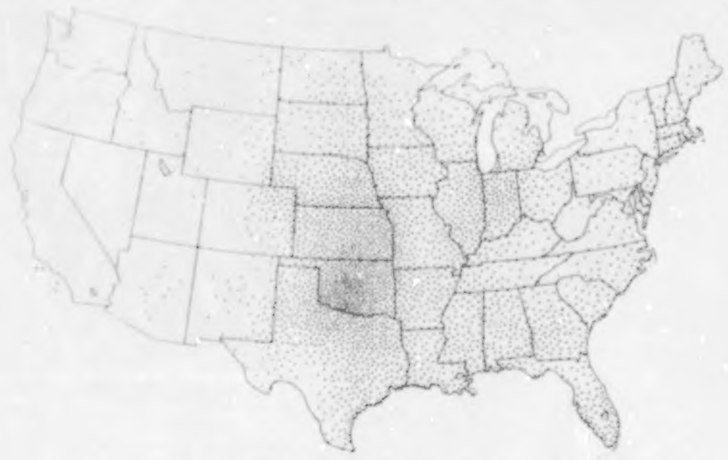
On the average, six hurricanes form in the South Atlantic each year and two strike the U.S. coast, generally from June to October. The most threatened areas are Texas, the Mississippi Delta section of Louisiana, South Florida, and the Carolinas. For example, there is a 13% chance that a hurricane will reach Key West in a given year and a 2% chance that it will be a great hurricane.

Hurricanes do damage in two ways: the high winds and storm surge (increased height and volume of water) directly damage buildings and other manmade structures; the rains carried by the hurricane cause extensive flooding on the coast and inland. The initial storm surge is responsible for 90% of the lives lost along the coast.

Roughly 6.6 million people live in the storm surge hazard zone, and 100 million people live in the wind hazard zone of hurricanes. The force and timing of a hurricane are usually known 12–24 hours in advance, giving residents time to evacuate.

Because of the rapid shift in population to the Gulf and south Atlantic coasts, the population at risk is growing. Eighty-six percent of the coastal population live in urban areas, so that emergency evacuation would be difficult if not impossible.

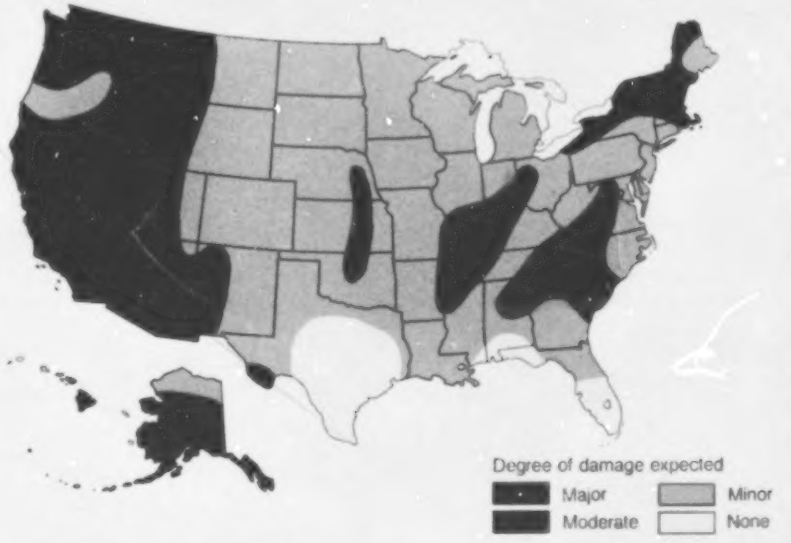
2-22
Frequency of tornadoes, 1953–1962



Each dot represents the approximate location of two occurrences during the 10-year period. An occurence is defined as the first point of contact with the ground.

Of the violent windstorms, tornadoes are the most common. They occur along the eastern and southeastern coasts, in the Midwest, and across the central portion of the western States. About 800 are recorded each year. Roughly one in ten causes damage of over $500,000. Tornadoes come quickly, provide little warning time, and are of short duration. The high winds—up to 260 miles per hour—damage or destroy structures, hurl debris, and overturn and destroy mobile homes and small aircraft.

2-23
Earthquake risk zones



Earthquakes occur primarily along the Pacific coast, especially in California, but most of the nation is at some risk. Major quakes have occurred in Missouri, Massachusetts, and South Carolina. Since 1800, the nation has been hit by 46 major quakes.

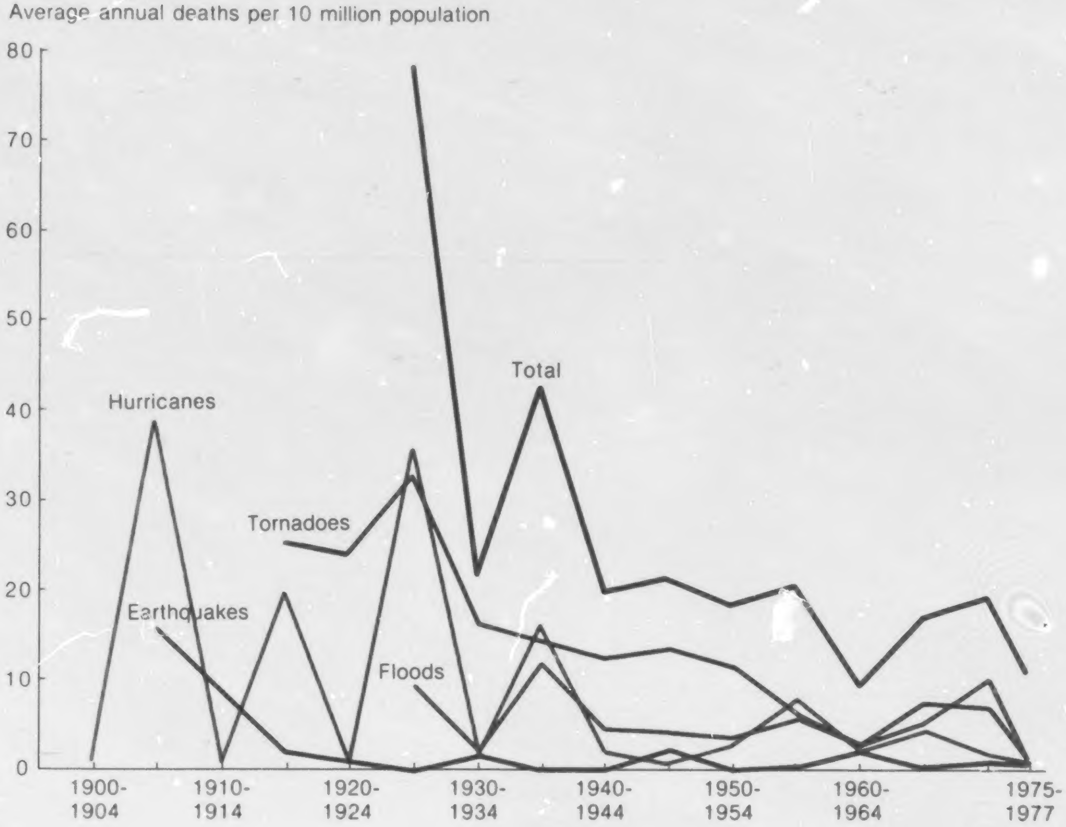
By vibrating the ground, earthquakes trigger landslides, avalanches, flooding, and fires—events that may be more damaging than the initial tremor. Underwater earthquakes cause great waves—tsunamis—that can destroy buildings along the coasts by impact and inundation.

An estimated 31 million people live in areas where a major destructive earthquake may occur. Some 600,000 people living along the Pacific coast and Hawaii are at risk from a 50-foot tsunami.

More than any other geophysical hazard, earthquakes are likely to produce almost complete social disruption, particularly in urban areas.

2-24

Loss of life from selected natural disasters, 1900–1977

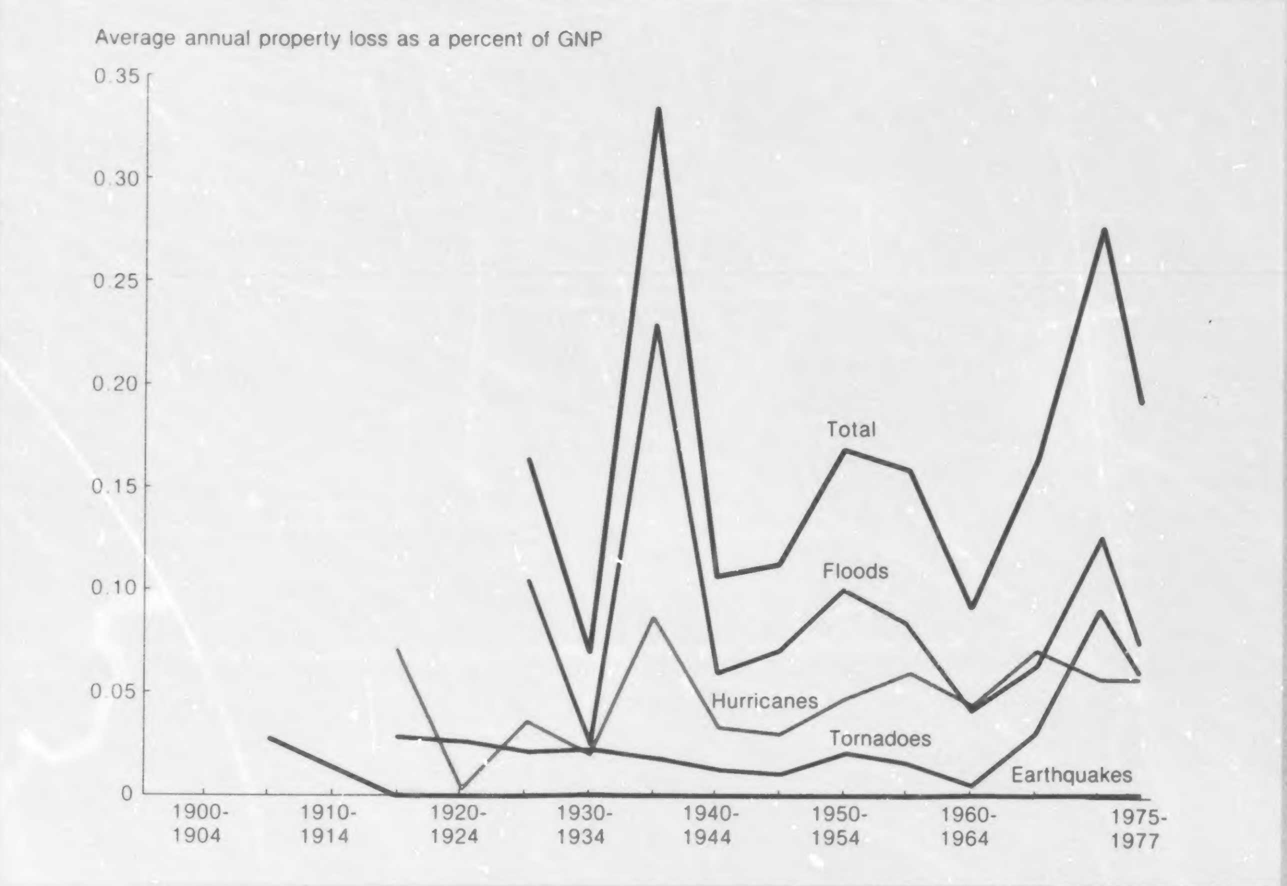


Loss of life from four natural disasters—floods, hurricanes, tornadoes, and earthquakes—has been declining over the past 50 years.

The wide fluctuations in number of deaths from hurricanes that characterized the first half of the century have been narrowed. Large losses of life from tornadoes, consistently the major cause of death from natural disasters, have dropped from 30 per 10 million in the 1920s to fewer than 10 per 10 million in the 1960s and 1970s. Loss of life from floods has not declined. Between 1970 and 1974, deaths from floods reached the highest levels in 40 years. Damaging earthquakes occur infrequently, and for many years no deaths were recorded.

2-25

Property damage from selected natural disasters, 1900–1977



Property damage from these four natural disasters has been increasing in the past 50 years. For the late 1970s, the average annual loss was estimated at $3.2 billion, about 0.2% of the gross national product. Losses have not grown in terms of the overall productive capacity of society, measured by the average annual dollar loss as a percentage of gross national product.

Floods are the major cause of property and crop losses.

The overall trend is one of decreasing loss of life but no long-term decrease in dollar losses. There is also a marked growth in the potential for catastrophic events because more people live and work in high-risk zones.

Sources and and technical notes

2-20

Urban population and lands affected by stream flooding, by Water Resources Region, 1967

Flood hazard in the United States: A research assessment, Gilbert F. White (Boulder: University of Colorado, 1975), monograph NSF-RA-E-75-006, p. 2, based on *List of urban places with information about flood problems*, U.S. Army Corps of Engineers (Washington, D.C., 1967) and *Statistical bulletin 317*, U.S. Department of Agriculture (Washington: USGPO, 1962).

Includes approximately 4,000 large urban areas with flood problems and refers to both direct and indirect effects.

The flash flood data were developed in 1976 by the American Red Cross for the National Weather Service, U.S. Department of Commerce.

2-21

Hurricane risk along the Gulf and Atlantic coasts

Hurricane hazard in the United States: A research assessment, Waltraud A. R. Brinkman (Boulder: University of Colorado, 1975), monograph NSF-RA-75-007, p. 6., based on *Atlantic hurricane frequencies along the U.S. coastline*, Simpson and Lawrence (Washington: U.S. Department of Commerce, 1971), NOAA tech. memo. NWS SR-58.

2-22

Frequency of tornadoes, 1953–1962

The national atlas of the United States of America, U.S. Geological Survey (Washington, D.C., 1975), p. 116.

Mobile home residents are particularly at risk from tornadoes. Their number increased dramatically during the 1960s, and for years the homes were not well anchored. An unanchored mobile home can be overturned by winds of 54 miles per hour; anchored mobile homes withstand winds of over 100 miles per hour. Improved construction and the use of tiedown equipment are providing more protection.

Data not available for Alaska and Hawaii.

2-23

Earthquake risk zones

Earthquake and tsunami hazards in the United States: A research assessment, Robert S. Ayre (Boulder: University of Colorado, 1975), monograph NSF-RA-E-75-005, p. 7, based on *Disaster preparedness; Report to the Congress*, Executive Office of the President, Office of Emergency Preparedness (Washington: USGPO, 1972), v. 1, 2, 3.

The map is based on the known distribution of damaging earthquakes and the modified Mercali intensities associated with these earthquakes; evidence of strain release; and consideration of major geologic structures and provinces believed to be associated with earthquake activity. The probable frequency of occurrence of damaging earthquakes in each zone was not considered in assigning ratings to the various zones.

Map revised 1969.

2-24

Loss of life from selected natural disasters, 1900–1977

Floods, 1925–1975: *Climatological data, annual summary 1977*, National Oceanic and Atmospheric Administration (Asheville, N.C., 1978), 28(13):117. 1976–1977: National Oceanic and Atmospheric Administration, National Weather Service, unpublished data.

Hurricanes, 1900–1934: *Historical statistics of the United States, colonial times to 1970*, U.S. Bureau of the Census (Washington: USGPO, 1975), p. 448. 1935–1977: *Climatological data, annual summary 1977*, National Oceanic and Atmospheric Administration (Asheville, N.C., 1978) 28(13):77.

Tornadoes, 1916–1977: *Climatological data, annual summary 1977*, National Oceanic and Atmospheric Administration (Asheville, N.C., 1978), 28(13):64.

Earthquakes, 1906–1971: *Earthquake and tsunami hazards in the United States: A research assessment*, Robert S. Ayre (Boulder: University of Colorado, 1975), monograph NSF-RA-E-005, table I-2, p. 27. 1972–1977: National Oceanic and Atmospheric Administration, unpublished data.

Population, 1900–1977: *Statistical abstract of the United States: 1978*, U.S. Bureau of the Census (Washington: USGPO, 1979), table 2, p. 6.

Average annual deaths per 10 million were calculated by dividing the average number of deaths for a given 5 years by the average annual resident population for the same period.

Lives lost, 1900–1924, are for selected years. Years reported for hurricanes are 1901, 1903, 1906, 1909, 1912, and 1915–1924. For tornadoes, the years are 1916–1924; for earthquakes, 1906, 1915, and 1918.

Hurricane data include North Atlantic tropical cyclones, storms that form in the tropics and that have winds of 39–73 miles per hour; hurricanes have winds of 74 miles per hour or higher accompanied by heavy rains, high waves, and tides.

Tornadoes are local storms of short duration formed of winds rotating at very high speeds, usually counterclockwise. These storms are visible as a vortex, a whirlpool of wind rotating about a hollow cavity in which centrifugal forces produce a partial vacuum. The fall in barometric pressure is so rapid that wooden structures are often lifted and burst open by the air confined within them.

Earthquake data include tsunamis. Earthquakes are a shaking or trembling of the earth that accompanies movement of its crust. Their magnitude is measured on a Richter scale, with the measurements increasing geometrically.

2-25

Property damage from selected natural disasters, 1900–1977

Hurricanes, 1915–1969; *Hurricane hazard in the United States: A research assessment*, Waltraud A. R. Brinkman (Boulder: University of Colorado, 1975), monograph NSF-RA-E-75-007, fig. III-1, p. 23. 1970–1977: *Climatological data, annual summary 1977*, National Oceanic and Atmospheric Administration (Asheville, N.C., 1978), 28(13):77.

Tornadoes, 1916–1977: *Climatological data, annual summary 1977*, 28(13):64.

Earthquakes, 1905–1969: *Earthquake and tsunami hazards in the United States: A research assessment*, Robert S. Ayre (Boulder: University of Colorado, 1975), monograph NSF-RA-E-75-005, table I-2, p. 27. 1970–1977: National Oceanic and Atmospheric Administration, unpublished data.

Gross National Product, 1905–1909: *Long-term economic growth, 1860–1970*, U.S. Department of Commerce (Washington: USGPO, 1973), data series A1, p. 182. 1910–1939: *Long-term economic growth, 1860–1970* (USGPO, 1973), data series A2, p. 183. 1940–1972: *Economic report of the President: Transmitted to the Congress, February 1974*, Council of Economic Advisers (Washington: USGPO, 1974), p. 250. 1973–1977: *Statistical abstract of the United States: 1978*, U.S. Bureau of the Census (Washington: USGPO, 1979), table 710, p. 441.

Implicit price deflator: *Long-term economic growth, 1860–1970* (USGPO, 1973), data series B61 and B62, pp. 222–223. *Economic report of the President: Transmitted to the Congress, February 1974* (USGPO, 1974), p. 252.

Population: *Statistical abstract of the United States: 1978* (USGPO, 1979), table 710, p. 441.

Average annual property loss as a percentage of gross national product was calculated by dividing the average annual loss from the four natural hazards by the average annual gross national product for each 5 years.

For hurricanes, 1970–1977, and tornadoes, 1916–1977, property damages are reported in ranges. The midpoint of the range was used for these years.

Chapter 3

Human Settlements

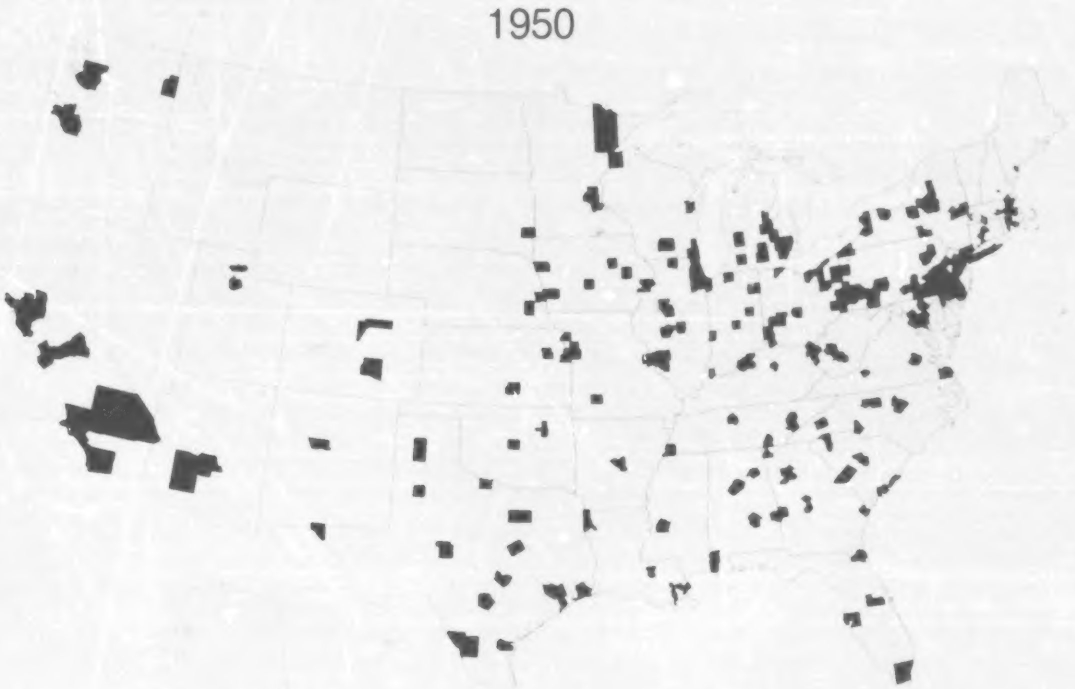
The dominant pattern of human settlement in the United States today is one of multicentered metropolitan regions. It is characterized by downtown towers, ethnic neighborhoods, suburban residential and commercial centers, factories in both cities and suburbs, and large acreages of cropland, pasture, forest, and other natural areas. This pattern of human settlement is found throughout all major regions of the country.

The change from the older urban-rural dichotomy to the newer, more integrated multicentered metropolitan area has come about primarily through major networks of highways, modern and efficient communication systems, and many new housing units. (More than half of all housing was built after 1955, more than two-thirds of it in suburban areas.)

The shift in living pattern is a direct response to the families and individuals who want to live in new housing in less dense areas. Almost every public opinion survey in recent years has shown a preference for living in smaller places, with low densities, more space, clean air, less noise, and other environmental amenities. The same trends are apparent in other industrialized societies, especially in Japan, West Germany, and Scandinavia.

New highways permit commuters to travel even greater distances to and from work, but the same highways helped to destroy older parts of the city, led to new forms of air pollution and noise disturbance, and created a situation in which most residents, particularly those outside central cities, depend almost completely on the automobile for maintaining their life styles.

3-1
Standard Metropolitan Statistical Areas, 1950



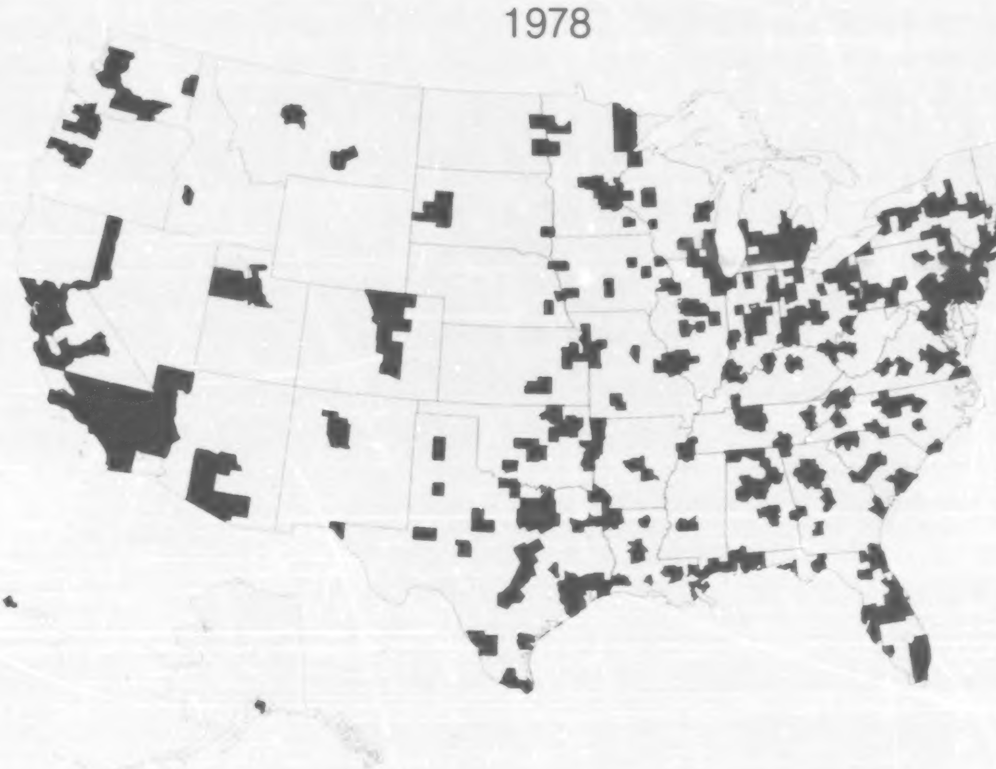
Metropolitan areas in the United States are growing in number, in population, and in the land that they occupy.

In 1950, there were 169 Standard Metropolitan Statistical Areas (SMSAs). They occupied 5.9% of the land and contained 56.1% of the population (85 million people). In 1978, there were 279 SMSAs occupying more than 14% of the land and containing 73% of the population (158 million people).

What makes today's metropolitan areas different from those of 1950 and earlier is the shift from a single downtown as the center of activity to many centers scattered throughout the area; more and more often they are located in the suburban rings.

3·2

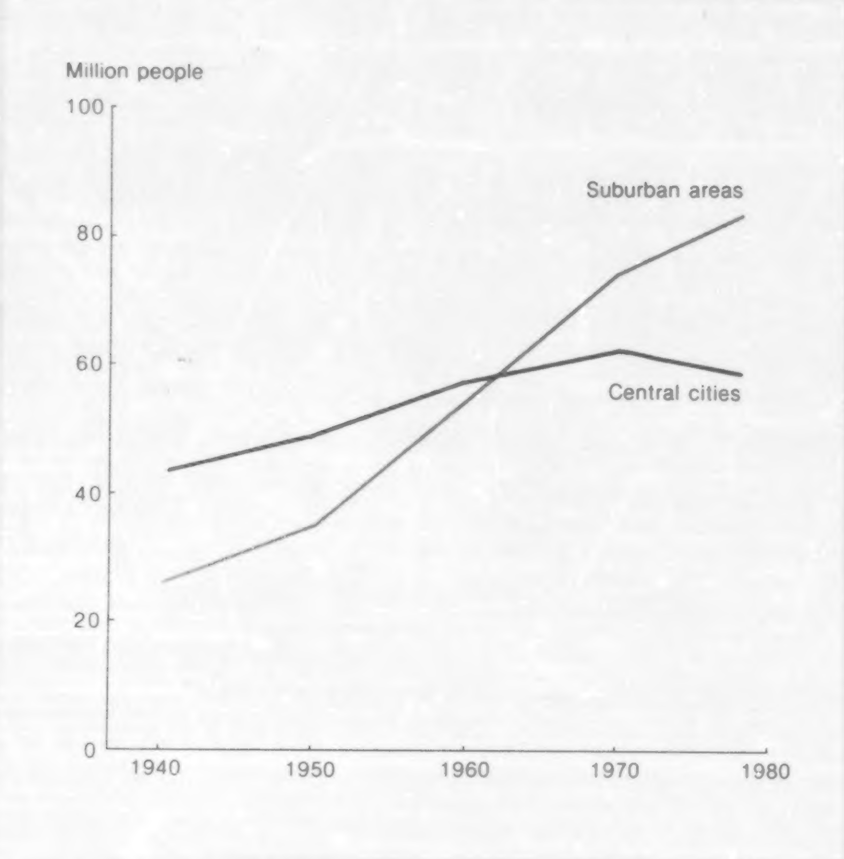
Standard Metropolitan Statistical Areas, 1978



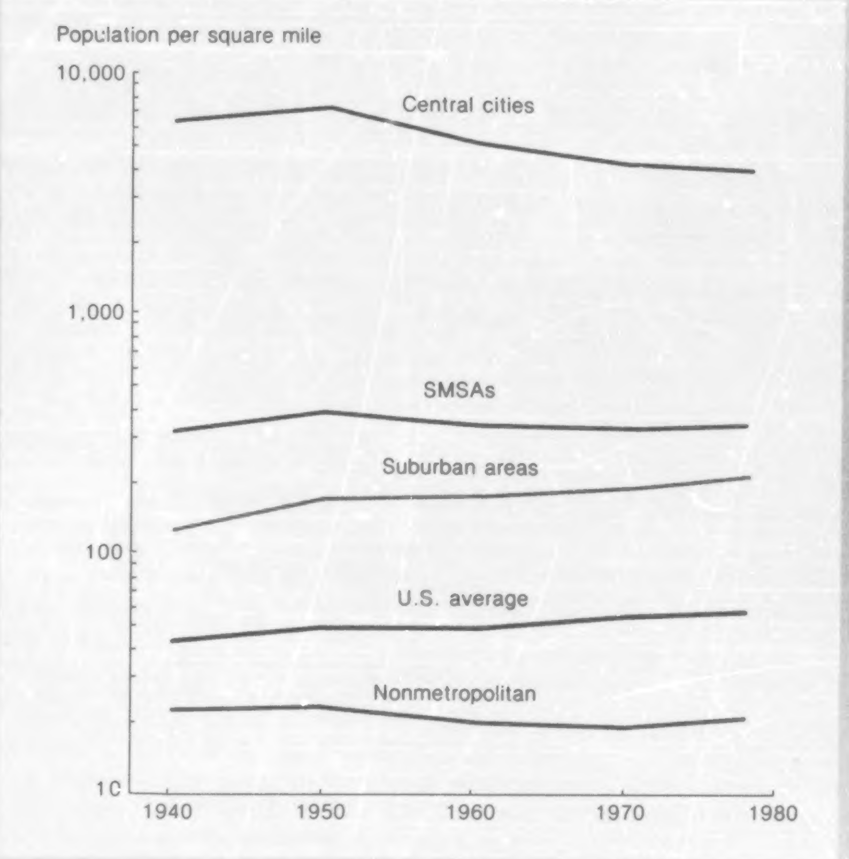
☐ A Standard Metropolitan Statistical Area (SMSA) is an integrated economic and social unit with a recognized urban population nucleus of substantial size. Each SMSA must include at least one city with 50,000 or more inhabitants or a city which has at least 25,000 inhabitants and which, with contiguous places having a population density of at least 1,000 persons per square mile, has a combined population of 50,000 and for general, economic, and social purposes constitutes a single community.

☐ The 1978 population is the total resident population as of July 1, 1977, in 279 SMSAs as defined December 31, 1978. The 1978 map refers to SMSAs designated as of November 14, 1978.

3-3
Population in suburban areas and central cities, 1940-1978



3-4
Population density, by location, 1940-1978



In fact, the suburbs dominate metropolitan areas. Since the early 1960s, people living in suburbs outnumber those living in central cities.

More people now live in suburban areas (39% in 1978) than in either central cities (28%) or nonmetropolitan areas (33%). This is a considerable change since 1950, when 44% lived in nonmetropolitan areas, 33% in central cities, and only 23% in the suburbs.

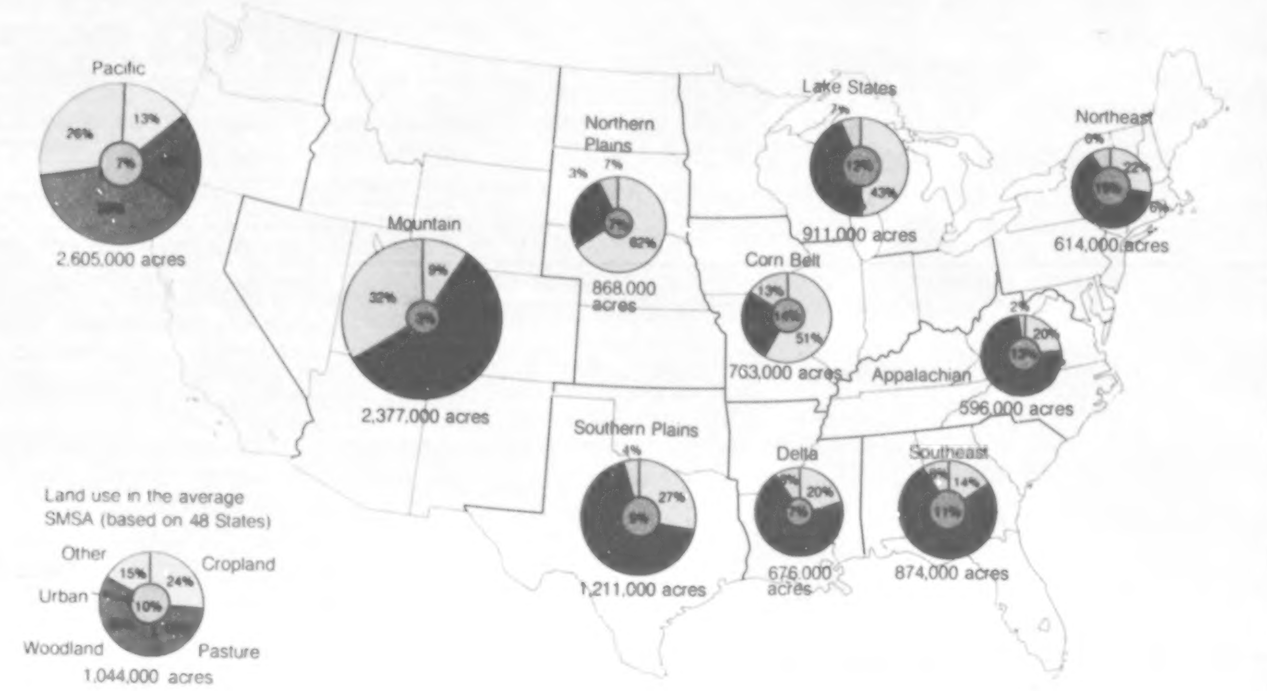
This change in where people live has changed the density of cities. Density in the central cities has declined from 7,517 per square mile in 1950 to 4,167 per square mile in 1978. At the same time, density in the suburbs increased from 175 to 223 people per square mile in 1978. (For the Nation as a whole, as the population has grown, density has increased from 51 people per square mile in 1950 to 61 people per square mile in 1978.)

89

90

3-5

Land use in Standard Metropolitan Statistical Areas, by region, 1970

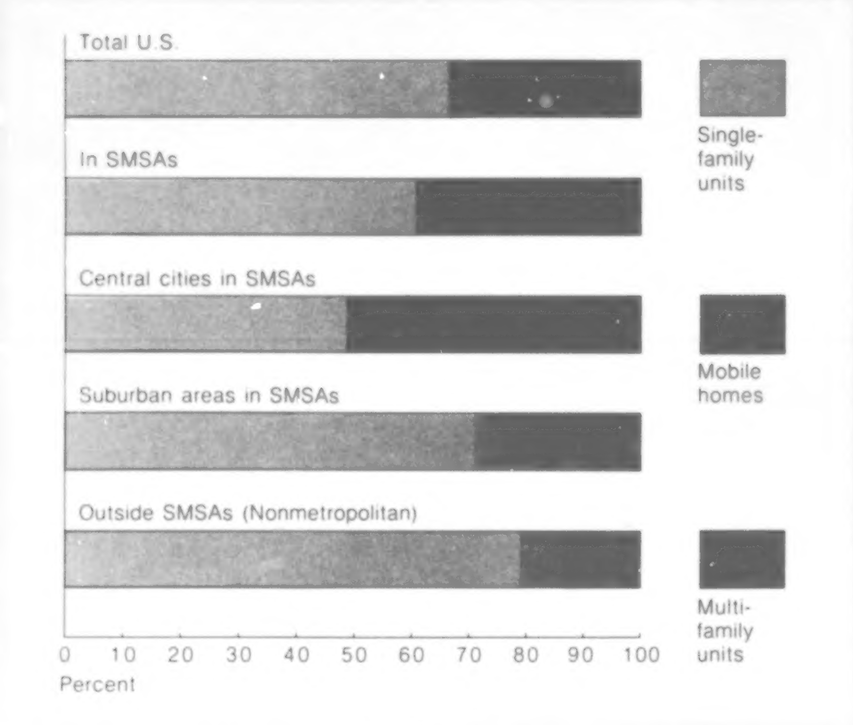

Pacific
13%
26%
7%
2,605,000 acres
Mountain
9%
32%
3%
2,377,000 acres
Northern Plains
3%
7%
7%
62%
868,000 acres
Lake States
7%
12%
43%
911,000 acres
Northeast
6%
22%
19%
6%
614,000 acres
Corn Belt
13%
14%
51%
763,000 acres
Appalachian
2%
20%
13%
596,000 acres
Southern Plains
4%
27%
9%
1,211,000 acres
Delta
20%
7%
676,000 acres
Southeast
14%
11%
874,000 acres
Land use in the average SMSA (based on 48 States)
Other
15%
24%
Cropland
Urban
10%
Woodland
Pasture
1,044,000 acres

No longer are city and country distinct entities. Rather, they exist side by side throughout a metropolitan area, forming a patchwork of urbanized and nonurbanized land.

On the average, only 10% of the land in metropolitan areas is urbanized. (The percentage varies from 19% in the Northeast to 3% in the Mountain States.) The remaining land is cropland, pasture, forest, or other natural area.

One result of this settlement pattern is an integration of land uses that offers a variety of employment, recreation, and life style. Another is dependence on the automobile. A third is intense competition for the land.

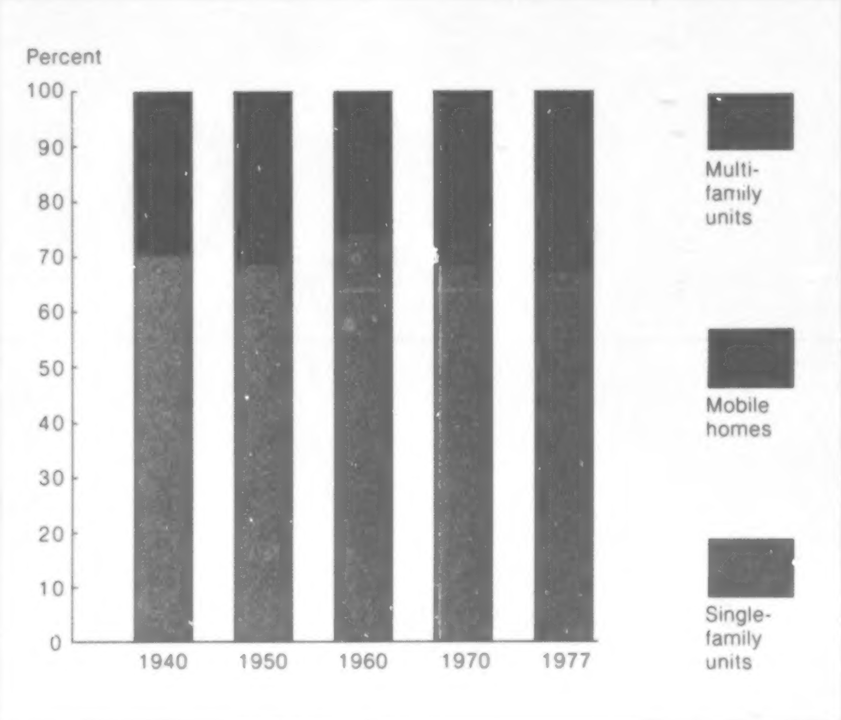
3-6
Composition of housing stock, by type of unit and location, 1977



The basic element of human settlements is the housing unit. It influences individual life style, transportation, neighborhood character, and even the development of newly urbanized areas.

By far the most common type of housing in the United States, accounting for 67.3% of all year-round dwelling units, is the single-family home, attached and detached. Single-family homes comprise nearly three-fourths of all housing in the suburbs.

3-7
Composition of housing stock, by type of unit, 1940–1977



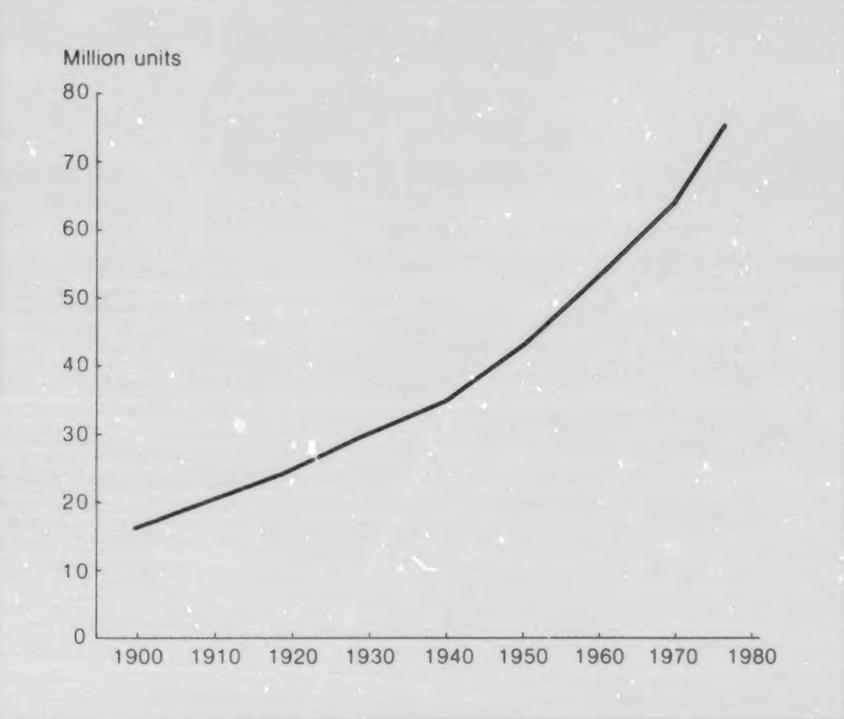
Multiunit structures account for 28.1% of the total housing inventory. They comprise half of all dwelling units in central cities.

Mobile homes and trailers make up the remaining 4.6% of the housing stock. Together they comprise 8% of housing in nonmetropolitan areas.

The percentage of single family units has remained about the same—near 70% since 1940, with a spurt during the 1950s to accommodate the post-World War II growth in families. By the late 1960s and early 1970s, there was a spurt in multi-family units as the postwar children set up housekeeping.

3-8

Occupied housing units, 1900–1977

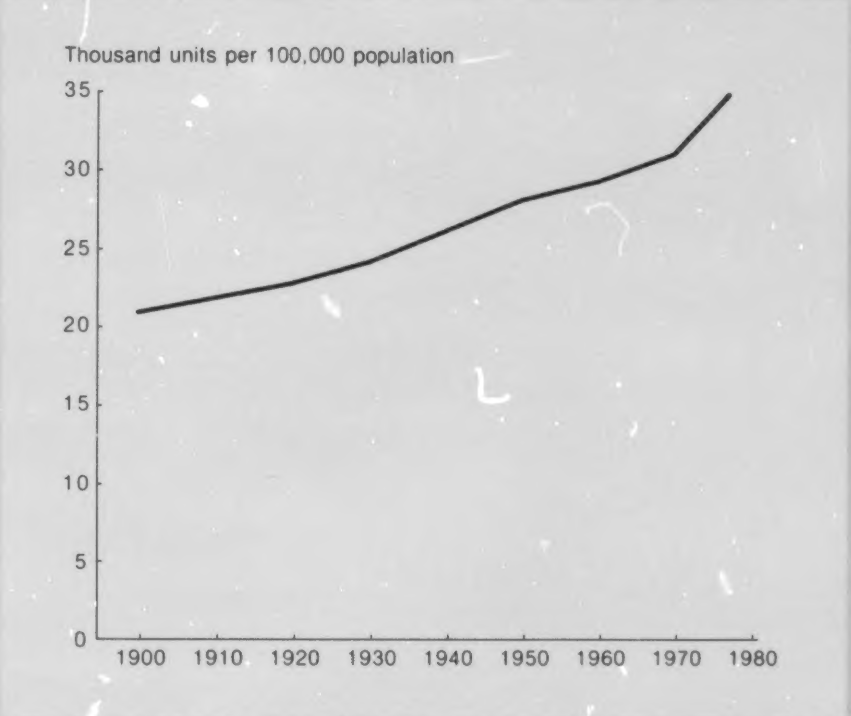


The total number of housing units has grown steadily since 1900. In 1977, there were 75.3 million occupied housing units and 7.1 million units that were vacant or were used only seasonally.

☐ Not all residences are officially designated housing units. In 1970, nearly 5.8 million people (2.8%) lived in army barracks, health institutions, prisons, or schools.

3-9

Occupied housing units, per 100,000 population, 1900–1977



The number of units is growing more rapidly than the population. In 1900, there was one unit for every five people and, in 1977, there was one for every three people.

The increase in number of units reflects the increase in number of households formed. Both young and old have been moving out of the larger family household to set up private housekeeping.

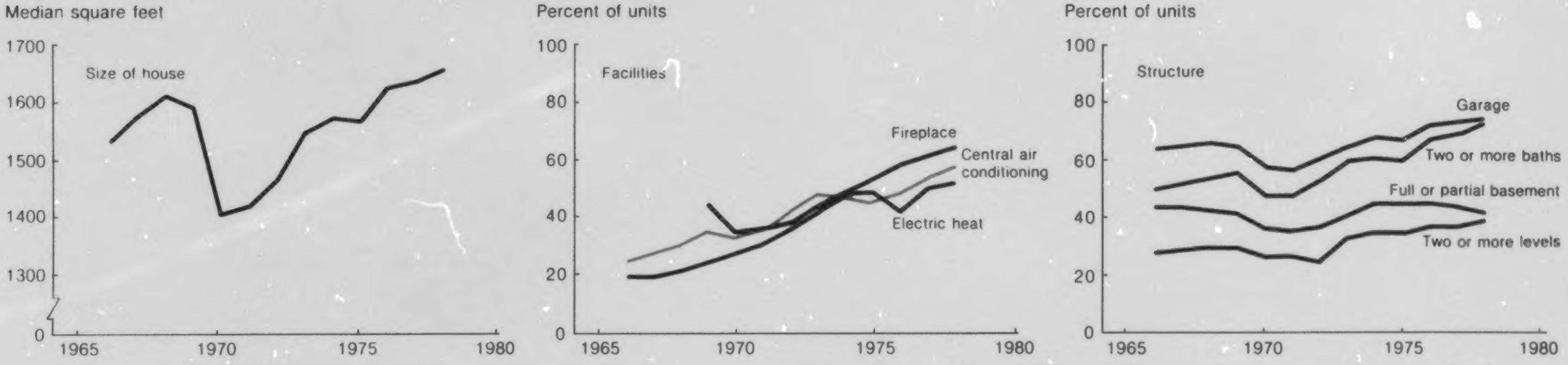
The change was rapid. In the 1960s, when population grew at a rate of 1.3% per year, households were formed at a rate of 1.9% per year. In the 1970s, with population growing at a rate of 0.8% per year, households were being formed at a rate of 2.3% per year.

☐ By definition, the number of households is equal to the number of occupied housing units; a household is one or more persons living together in a single housing unit.

☐ As the number of households has increased and the number of children per family has declined, household size has also dropped. In 1900, the average household had 4.8 persons; in 1977, it had 2.9 persons.

3-10

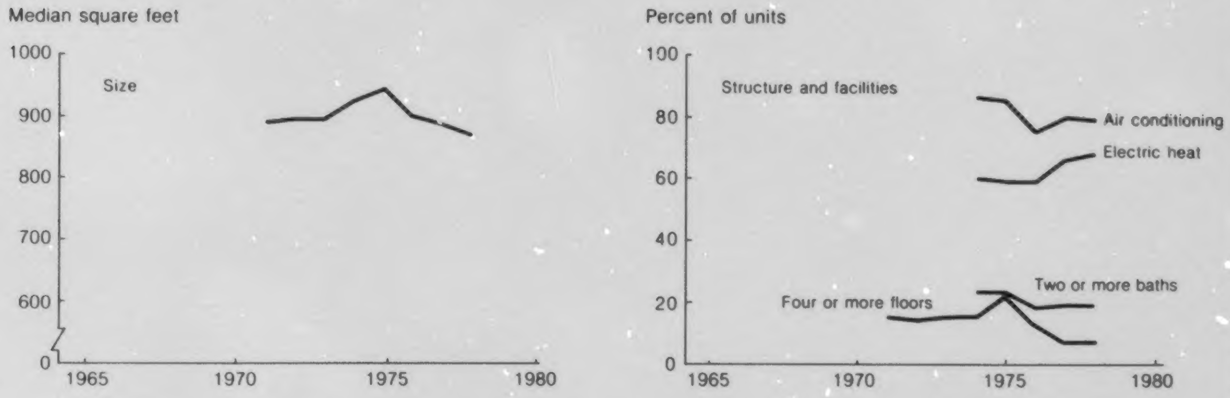
Characteristics of new single-family housing units, 1966–1978



Single-family units built in the past 10 years are larger and are supplied with more elaborate and extensive facilities than older units. Of the amenities, central air conditioning and electric heat have been incorporated the most often.

☐ The average size of new housing declined in 1970–1972 because there was an unusually high number of low- and medium-priced homes available. These houses tend to be smaller and to have fewer amenities.

3-11
Characteristics of new multifamily housing units, 1971–1978



New multifamily units are slightly more than half the size of the single-family units, but more are air conditioned and heated electrically. They also contain fewer bathrooms, fireplaces, and other amenities.

☐ The presence of air conditioning varies by region. In 1976, about 93% of multifamily units built in the South were air conditioned; in the North Central States, it was 85%; in the Northeast, 78%; and in the West, 51%. In 1976, fewer multifamily housing units were completed in the South than in previous years, thus reducing the national average for air conditioning to 75%.

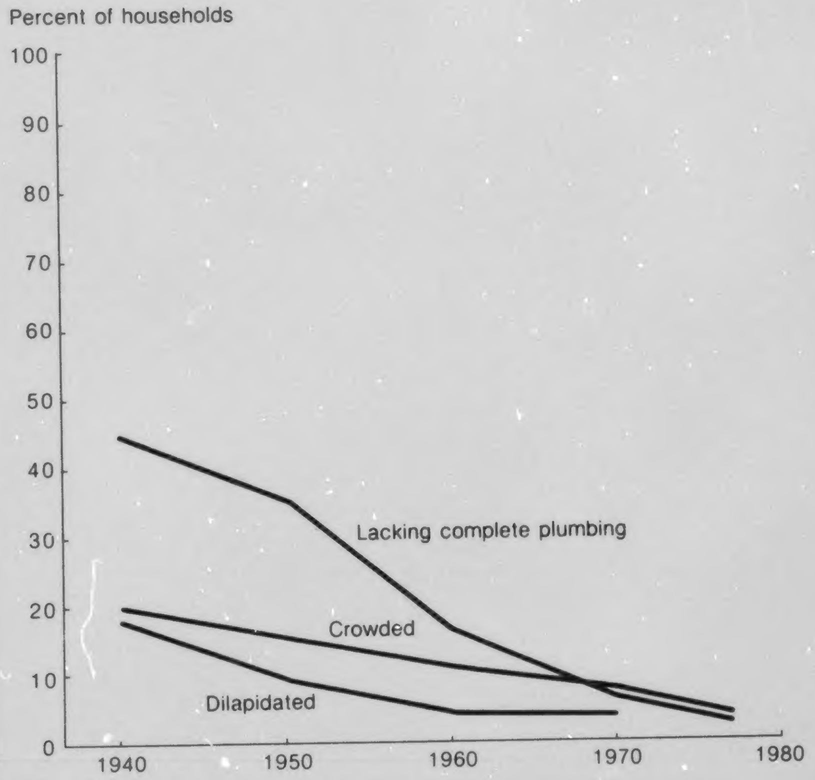
3-12
Condition of housing, 1940–1977

Most housing in the United States now meets the needs for basic facilities—hot water, heat, refrigerator, stove, plumbing—comfort, and structural soundness.

Since 1940, the percentage of households without major plumbing dropped from 44.6% to 3.1% in 1977; in housing that is "crowded" (more than one person per room), from 20.2% to 4.4% in 1977; and in housing that is dilapidated, from 18.1% to 4.5% in 1970 (a 1977 figure is not available for dilapidation).

This change in quality came about as new units with more complete equipment were added to the stock and the old units were renovated, abandoned, or demolished.

The emphasis today is not so much on basic facilities as on attaining housing with a wide assortment of amenities.

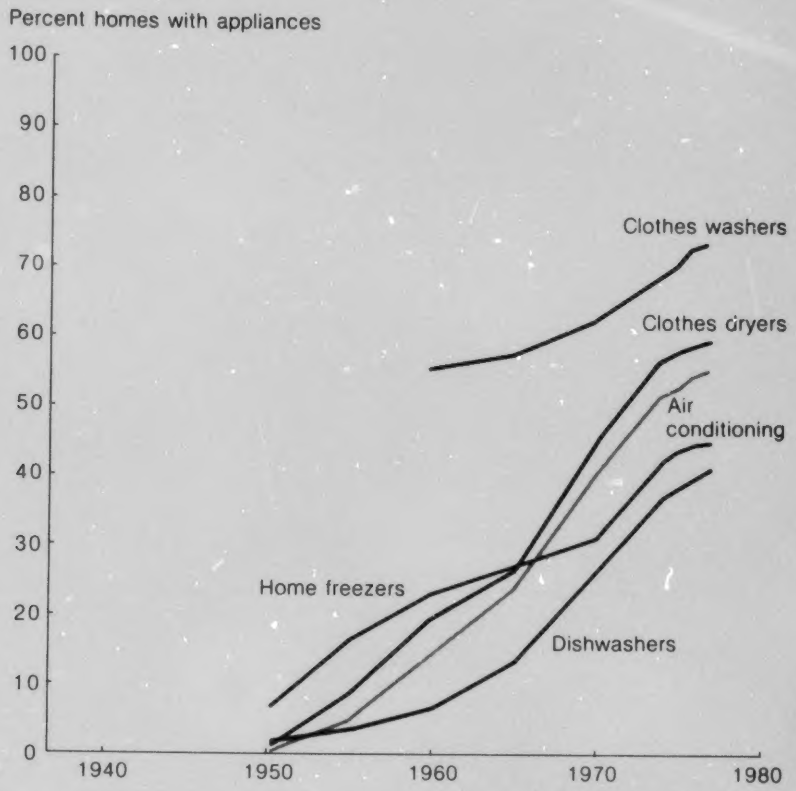


99

3-13

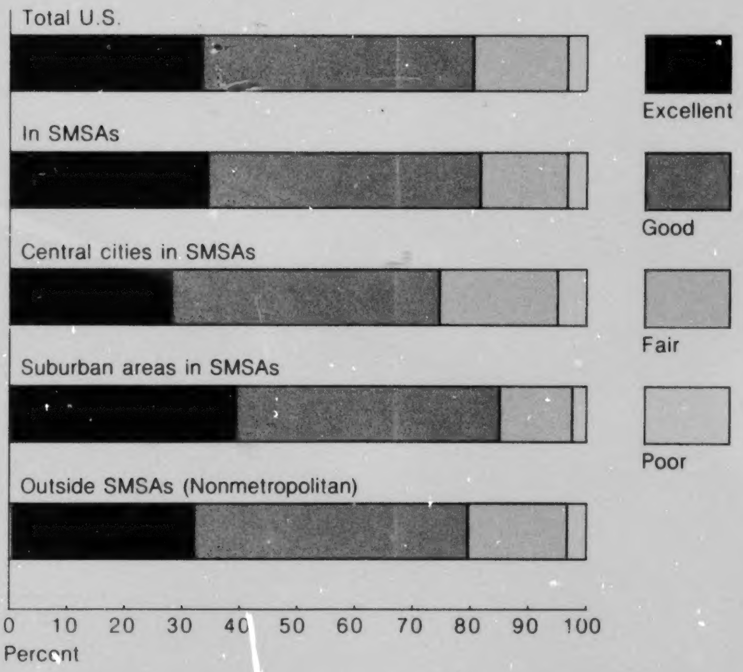
Homes with selected major electric appliances, 1950–1977

In addition to basic facilities, an increasing number of homes now have time-saving and human energy-saving appliances: clothes washers, clothes dryers, room air conditioners, home freezers, and dishwashers.



3-14

Overall opinion of living unit, by location, 1977



In general, people think that their housing is quite good. In 1977, 34% of the households surveyed rated their housing excellent, and 46% rated it good.

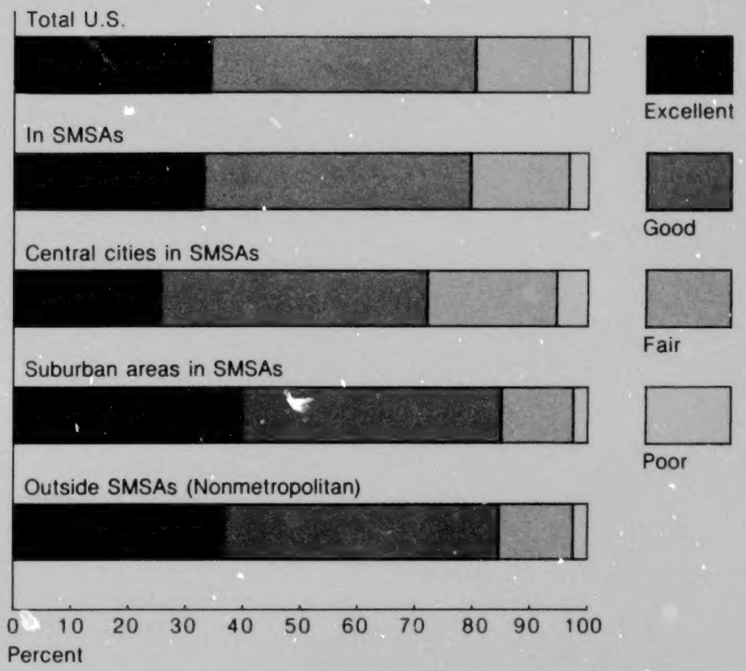
Consistently higher ratings are given by suburban residents than by central city residents.

People in Canada and the United States rank their housing higher than do people in other areas of the world: 55% of Canadian and U.S. residents rank their housing as high, compared with 49% of western Europeans, 37% of Latin Americans, 14% of Africans, and 14% of Asians.

☐ The question asked was "How would you rate this house (building) as a place to live? Would you say it is excellent, good, fair, or poor?"

3-15

Overall opinion of neighborhood, by location, 1977

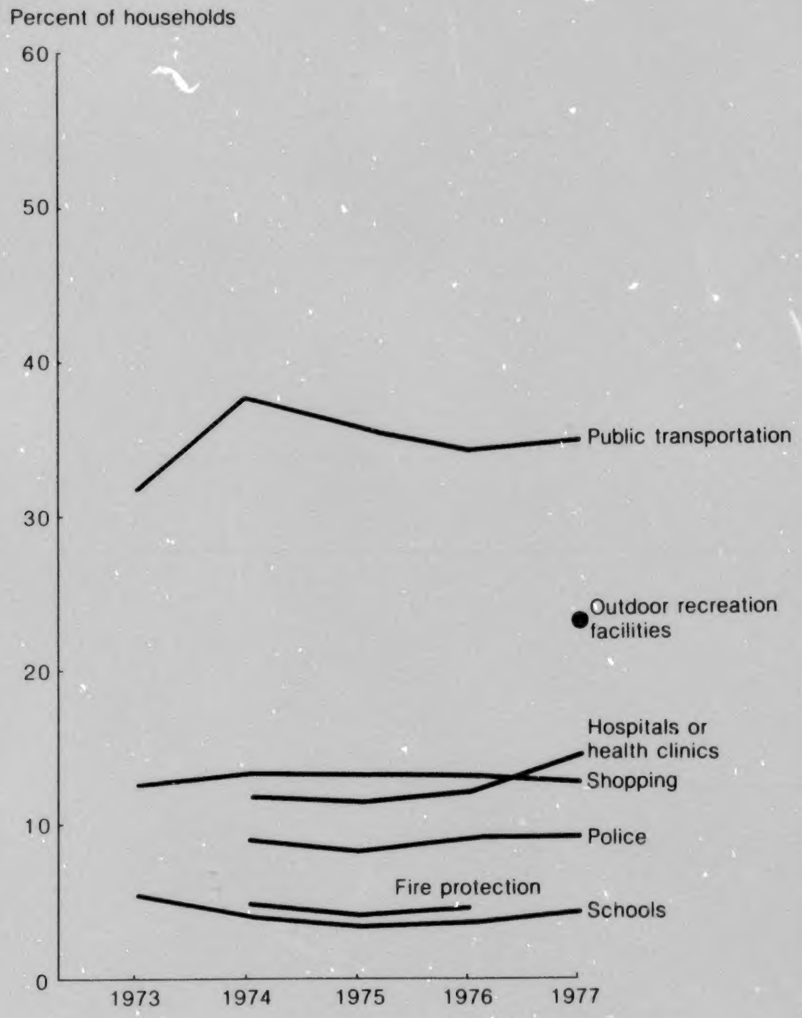


A neighborhood may encompass a square mile or more of land and houses, or it may be a single building or even a single floor in a large building. More than simply a geographic area, a neighborhood is a set of social and physical relationships with which people identify.

Evaluation of neighborhoods was similar to that for housing, with more than a third of all residents rating their neighborhoods excellent and nearly half of all residents rating their neighborhoods good. Consistently higher ratings were again given by suburban residents than by central city residents.

☐ The question asked was "In view of all the things we have talked about, how would you rate this neighborhood as a place to live? Would you say it is excellent, good, fair, or poor?"

3-16
Inadequate neighborhood services, 1973–1977

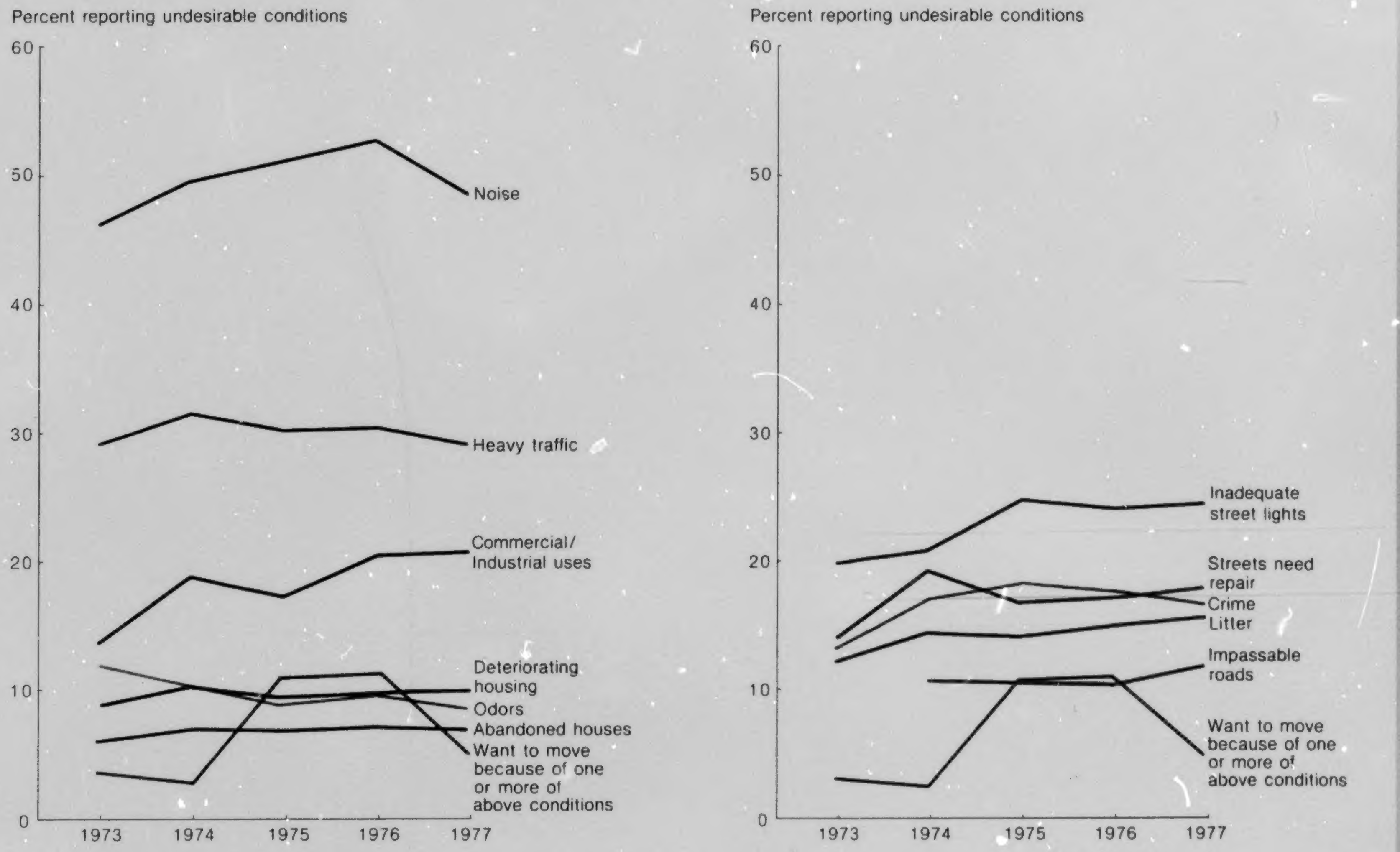


When asked about neighborhood services, one problem—inadequate public transportation—was mentioned more often than any other, especially by suburban and nonmetropolitan residents.

☐ The questions asked were
(1973) "Do you have inadequate or unsatisfactory public transportation, schools, neighborhood shopping such as grocery stores or drug stores?" (Yes/No)
(1974–1976) "Do you have adequate or satisfactory public transportation, schools, neighborhood shopping such as grocery stores or drug stores, police protection, fire protection, hospitals or health clinics?" (Yes/No/Don't know)
(1977) "Do you have satisfactory public transportation, schools, neighborhood shopping such as grocery stores or drug stores, police protection, outdoor recreation facilities such as parks, playgrounds or swimming pools, hospitals or health clinics?" (Yes/No/Don't know)

3-17

Neighborhood deficiencies, 1973–1977



When asked about the deficiencies in their neighborhoods, people most often mentioned noise, then heavy traffic and inadequate street lighting.

With the exception of inadequate street lights and streets in need of repair, more central city residents than suburban residents reported neighborhood deficiencies.

☐ The questions asked were:

(All years) "Here is a list of conditions which many people have on their streets. Which, if any, do you have? Street (highway) noise? Heavy traffic? Streets or roads continually in need of repair or open ditches? Roads impassable due to snow, water, etc.? [not asked in 1973] Poor street lighting? Neighborhood crime? Trash, litter, or junk in the streets (roads), or on empty lots, or on properties in this neighborhood? Boarded-up or abandoned structures? Occupied housing in rundown condition? Commercial, industrial, or other nonresidential activities? Odors, smoke, or gas? Noise from airplane traffic?" (Yes/No)

(1973–1976) "Is (the condition) so objectionable that you would like to move from the neighborhood?" (Yes/No)

(1977) "Which of these four categories best describes how you feel about (condition)?" (Does not bother you/Bothers you a little/Bothers you very much/Bothers you so much you would like to move.)

3-1
Standard Metropolitan Statistical Areas, 1950

U.S. census of population: 1950, U.S. Bureau of the Census (Washington: USGPO, 1952), v. 1, fig. 13, p. xxxiv.

3-2
Standard Metropolitan Statistical Areas, 1978

State and metropolitan area data book, 1979, U.S. Bureau of the Census (Washington: USGPO, 1980), pp. xii–xiii.

3-3
Population in suburban areas and central cities, 1940–1978

1940–1960: *1960 census of population*, U.S. Bureau of the Census (Washington: USGPO, 1964), v. 1, U.S. summary and previous decennial issues; U.S. Bureau of the Census, Population Division, unpublished data.

1970–1978: *Current population reports*, U.S. Bureau of the Census (Washington: USGPO, 1979), series P-20, n. 336, table 19, p. 34.

Each SMSA is divided into two areas: "central city" and "outside central city." Suburban areas here refer to outside central cities.

Population data are not strictly comparable.

1940 and 1950: Resident population in 168 SMSAs as defined by the 1950 census. Excludes Alaska and Hawaii, which were admitted to the Union in 1959.

1960: Resident population in 209 SMSAs as defined by the 1960 census.

1970 and 1978: Civilian noninstitutional population in 243 SMSAs as defined by the 1970 census.

3-4
Population density, by location, 1940–1978

See 3-3.

Density data are not strictly comparable. See note in 3-3 for population differences.

1940 and 1950: Area as defined by the 1950 census.

1960 and 1970: Area as defined by the 1960 and 1970 censuses, respectively.

1978: Area as defined by the 1970 census.

3-5
Land use in Standard Metropolitan Statistical Areas, by region, 1970

Farming in the city's shadow, USDA Economic Research Service (Washington: USGPO, 1974), agr. econ. rep. 250, fig. 3, pp. 6–7.

Data refer to the average size of SMSAs in each region. Regions are USDA farm production regions.

3-6
Composition of housing stock, by type of unit and location, 1977

Annual housing survey: 1977, U.S. Bureau of the Census (Washington: USGPO, 1979), part A, p. 1.

Data include 80.7 million year-round housing units and exclude 1.7 million vacant (seasonal and migratory) units. The annual housing survey includes the 50 States and the District of Columbia.

Single-family units are primarily detached houses. This category also includes two or more attached townhouses which are separated by an unbroken ground-to-roof wall (no common basement or attic) and which have their own separate utilities.

Multifamily units consist of two or more attached units which share utilities (such as plumbing) and have no ground-to-roof wall separating them.

Mobile homes include mobile homes and trailers.

3-7
Composition of housing stock, by type of unit, 1940–1977

1940: *16th census of the United States: 1940, housing*, U.S. Bureau of the Census (Washington: USGPO, 1943), v. II, part 1, table 4, p. 10.

1950: *Census of housing: 1950 (taken as part of the 17th decennial census of the United States)* (USGPO, 1953), v. I, part 1, table 5, p. 1–3.

1960: *1960 census of housing (taken as part of the 18th decennial census of the United States* (USGPO, 1963), v. I, part 1, table 5, pp. 1–16 to 1–21.

1970 and 1977: See 3-6.

3-8
Occupied housing units, 1900-1977

1900–1910: *Historical statistics of the United States, colonial times to 1970*, U.S. Bureau of the Census (Washington: USGPO, 1975), p. 646.

1920–1970: *Statistical abstract of the United States: 1978*, U.S. Bureau of the Census (Washington: USGPO, 1978), table 1377, p. 792.

1977: See 3-6.

3-9
Occupied housing units, per 100,000 population, 1900-1977

See 3-8.

Statistical abstract of the United States: 1978, U.S. Bureau of the Census (Washington: USGPO, 1978), table 2, p. 6.

3-10
Characteristics of new single-family housing units, 1966-1978

Size of house, 1966–1970: *Characteristics of new one-family homes: 1974*, U.S. Bureau of the Census (Washington: USGPO, 1975), constr. rep. series C25-74-13, p. 103. 1971–1975: *Characteristics of new housing: 1975* (USGPO, 1976), constr. rep. series C25-75-13, p. 54. 1976–1978: *Characteristics of new housing: 1978* (USGPO, 1979), constr. rep. series C25-78-13, p. 53.

Structure and facilities, 1966–1971: *Characteristics of new one-family homes: 1974*, pp. 33, 39, 45, 51, 57, 75, 81. 1972–1977: *Characteristics of new housing: 1977* (USGPO, 1978), constr. rep. series C25-77-13, pp. 34, 42, 43. 1978: *Characteristics of new housing: 1978*, pp. 32, 38, 39.

Data on size of house include new single-family houses sold, including townhouses.

Data on structure and facilities include homes sold and contractor-built, owner-built, and rental home started in 1966–1970. For 1971–1978, they include privately owned single-family houses completed.

Percentages exclude houses for which questions were not answered.

Two or more stories include split-level homes.

3-11
Characteristics of new multifamily housing units, 1971-1978

1971–1973: *Characteristics of new housing: 1975*, U.S. Bureau of the Census (Washington: USGPO, 1976), constr. rep. series C25-75-13, table 17, pp. 42–44. 1974–1978: *Characteristics of new housing: 1978* (USGPO, 1979), constr. rep. series C-25-78-13, pp. 44–46.

Data refer to privately owned multifamily units completed. Air conditioning refers to both central air conditioning and individual room units.

3-12
Condition of housing, 1940-1977

1940: *Social indicators, 1973*, U.S. Office of Management and Budget (Washington: USGPO, 1973), pp. 206, 209, from *16th census of the United States: 1940, housing*, U.S. Bureau of the Census (Washington: USGPO, 1943), v. II, part 1, pp. 16, 38.

1950–1970: *Housing in the seventies*, U.S. Department of Housing and Urban Development (Washington: USGPO, 1973), p. 6-4, from *1970 census of housing*, U.S. Bureau of the Census (Washington: USGPO, 1972), and previous decennial issues.

1977: See 3-6, pp. 2, 4.

Lacking complete plumbing, 1940: Lacking some or all basic plumbing facilities—private bath, private flush toilet, running water. 1950–1970: Lacking one or more plumbing facilities or sharing a facility. 1977: Lacking some or all plumbing facilities.

Crowded: More than one person per room.

Dilapidated, 1940: Needing major repair—a unit with serious defects which require repair or replacement or a unit continued neglect of which would jeopardize soundness of the structure or safety of the occupants. 1950–1970: A unit which does not provide safe and adequate shelter and endangers health, safety, or well-being of the occupants. Defects are so critical or widespread that the structure should be extensively repaired, rebuilt, or torn down.

3-13
Homes with selected major electric appliances, 1950-1977

Merchandising (New York: Billboard Publications, 1978) and previous annual issues.

Estimates are based on appliances shipped by manufacturers, appliances, purchased from retailers (initial purchases and replacements), and lifetime expectancies of appliances.

Percentages refer to the number of homes wired for electricity (75.8 million in 1977).

Clothes washers, 1950 and 1955: Available data are not comparable and are therefore excluded.

3-14
Overall opinion of living unit, by location, 1977

See 3-6, part B, p. 8.

3-15
Overall opinion of neighborhood, by location, 1977

See 3-6, part B, pp. 17–18.

3-16
Inadequate neighborhood services, 1973-1977

See 3-6, part B, pp. 16–17, and previous annual issues.

3-17
Neighborhood deficiencies, 1973-1977

See 3-6, part B, pp. 13–15, and previous annual issues.

Chapter 4

Transportation

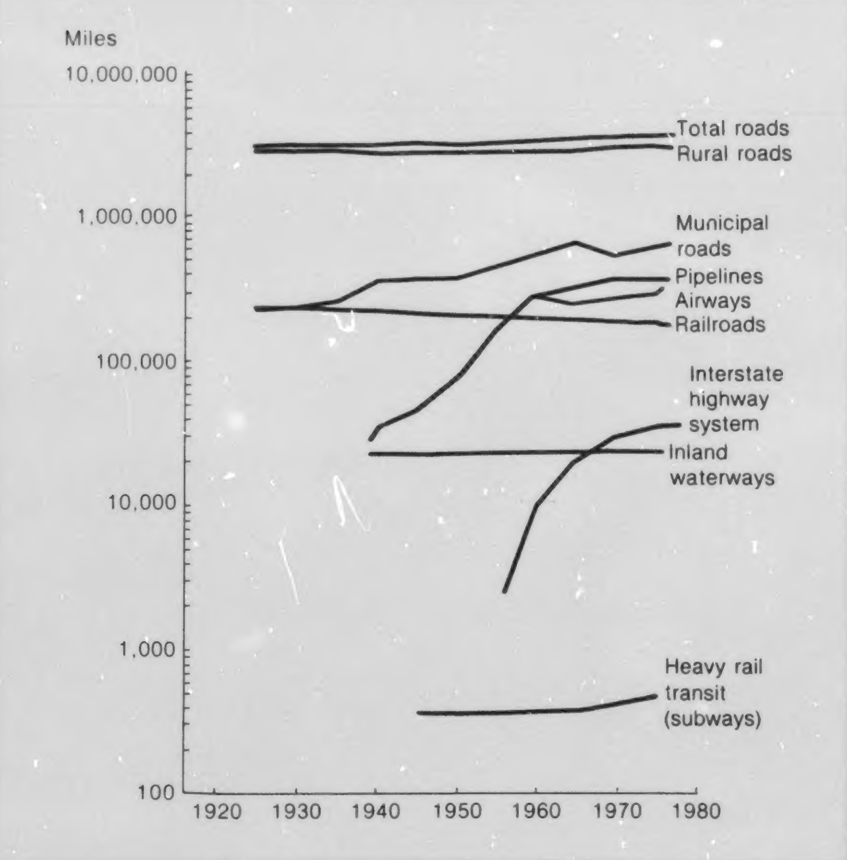
Land, air, and water rights-of-way and the vehicles that travel them are a major part of the manmade environment. Highways, railways, and pipelines crisscross the land. Air service reaches every large city and many of moderate size. The coasts are dotted with docks and support facilities for ships that carry goods to and from the United States.

These networks are used to move goods and people. In 1977, 2,331 billion ton-miles of interstate freight were moved by rail, pipe, truck, water, and air. Each year, the average person travels more than 12,000 miles by car, truck, plane, or other means. In 1975, 83% of all households owned or leased an automobile, and 35% owned two or more. Counting trucks, buses, planes, boats, and all forms of motorized land vehicles, there are more than two vehicles for every household in the country.

Development and use of these networks have changed the shape of cities and have helped create suburban living. They now permit many people to travel long distances to work and shop.

They have also transformed the environment. Building roads, highways, railroads, airports, waterways, and docks has caused substantial damage to natural systems, particularly wildlife habitats. Motor traffic is a prime source of air pollution. Transportation as a whole is a prime user of fossil fuel. Air and road traffic are prime sources of noise.

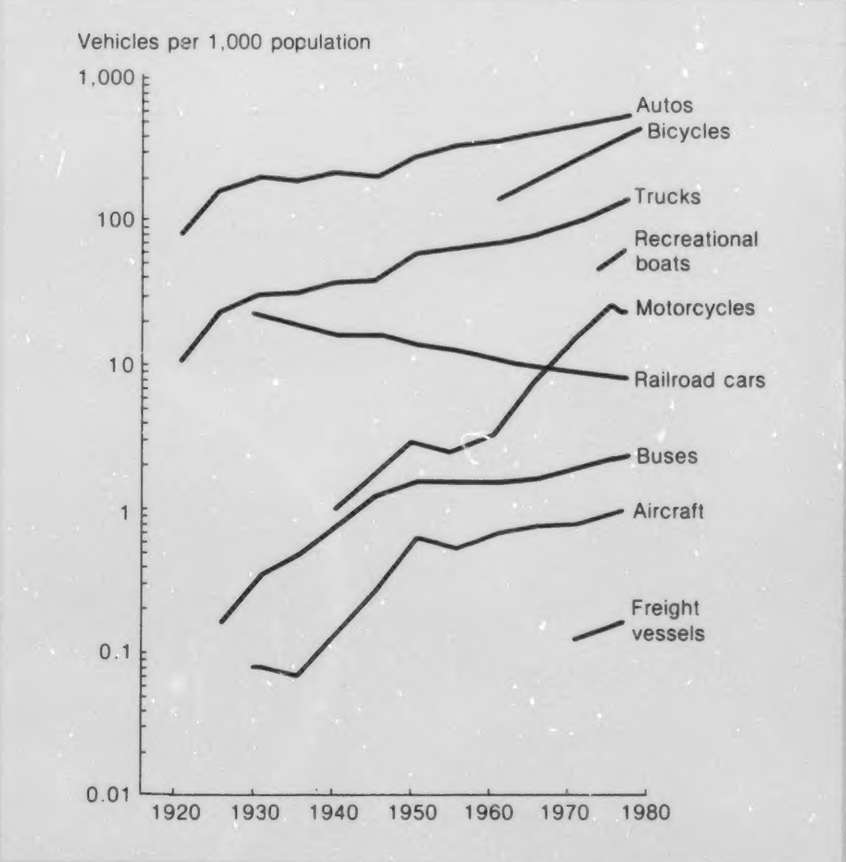
4-1
Major transportation networks, 1925–1978



Railways, airways, highways, waterways, and pipelines are the major components of the transportation system. Most of these components are now growing slowly, if at all.

About 18% of the nation's 3,867,000 miles of highways and roadways are located within cities and towns. Of all transportation networks, highways and roadways occupy by far the largest land area.

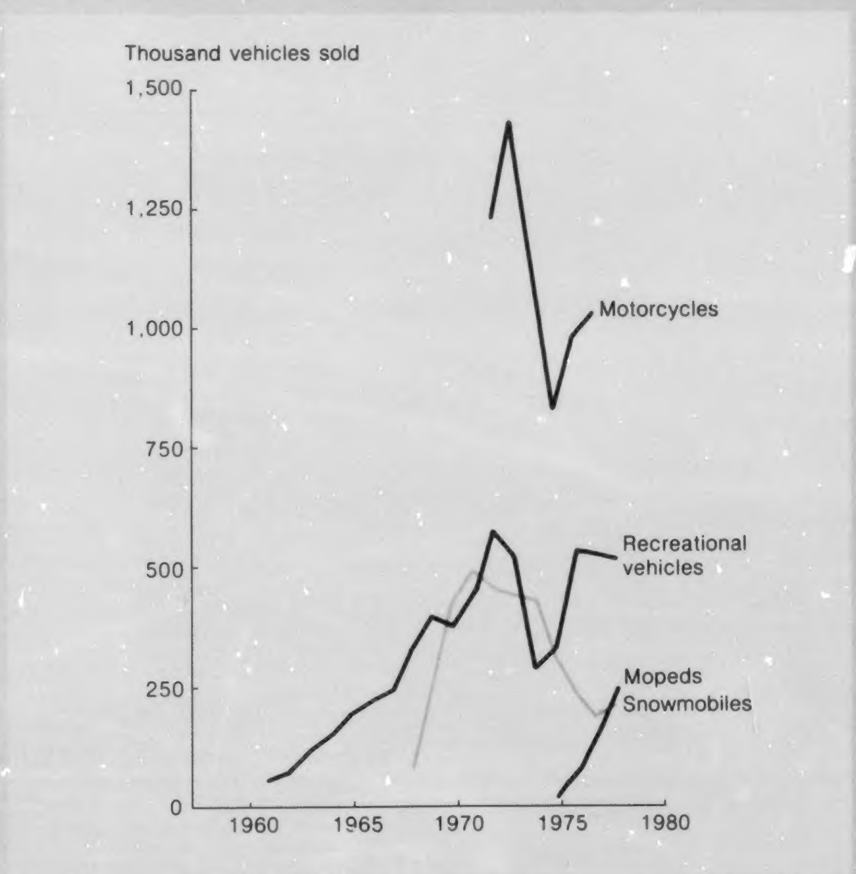
4-2
Transportation vehicles, 1920–1978



The number of vehicles in use has continued to grow since World War II. Only the number of railroad cars in use is decreasing.

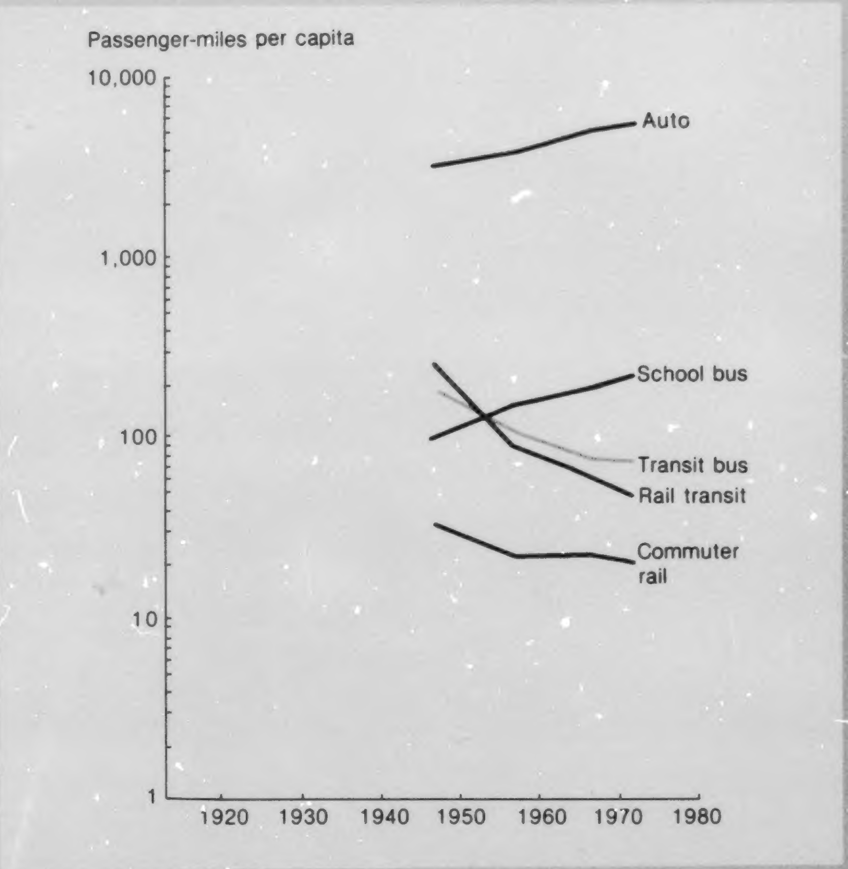
The great number of automobiles, trucks, and bicycles reflects the importance of personal transportation in the United States. In 1977, there was one automobile for every two people.

4-3
Sales of specialized vehicles, 1961–1978



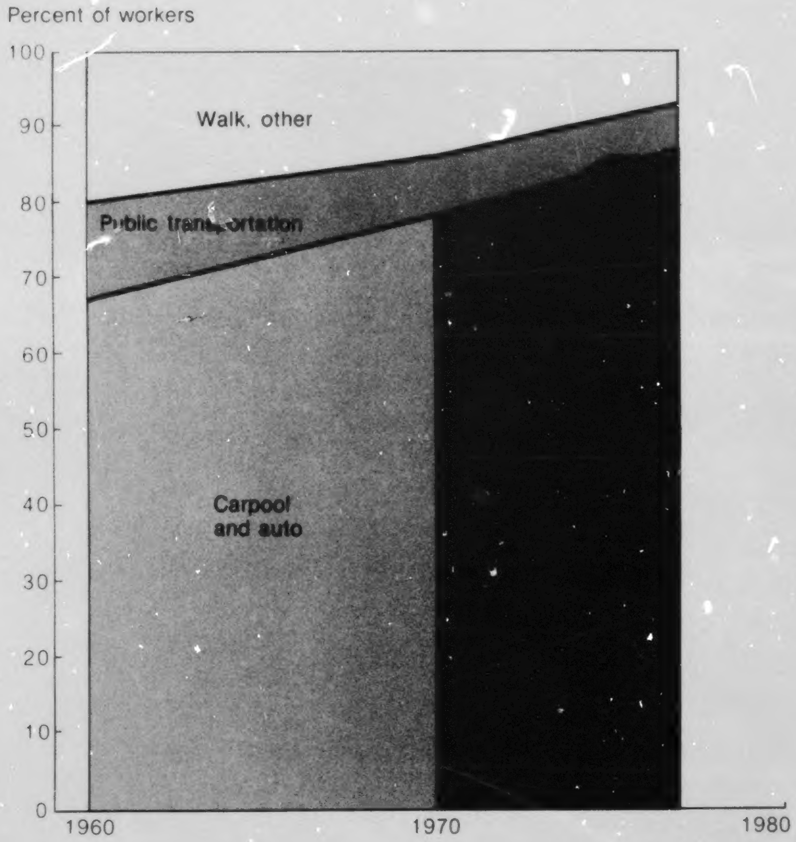
Sales of specialized vehicles reflect the growing diversity in personal transportation. Motorcycles are the most popular, followed by recreation vehicles (travel trailers, truck campers, motor homes, and camping trailers), mopeds (lightweight motorized bicycles), and snowmobiles.

4-4
Local passenger travel, 1950–1975



The auto is the dominant means of local travel. The other forms of local travel—bus and rail—account for less than 10% of all local mileage traveled per person.

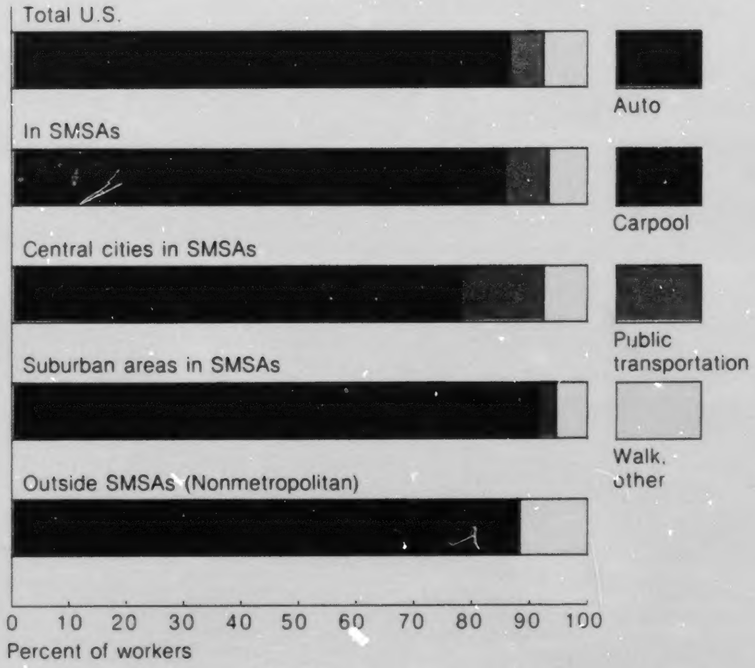
4-5
Principal means of transportation to work, 1960–1977



Rush hour—when commuter demand for fast and comfortable travel peaks—puts the greatest stress on local transportation systems.

Nationally, commuters have opted for private transportation. In 1977, 87% of workers relied on the automobile as their principal means of getting to work, and 16.2% used carpools. Workers using public transportation declined from 12.6% in 1960 to 5.4% in 1977.

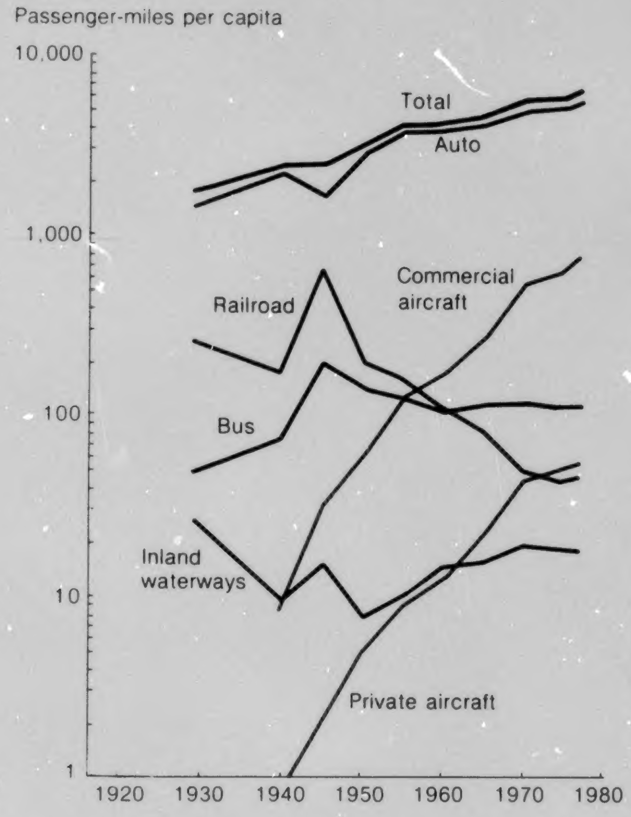
4-6
Principal means of transportation to work, by location, 1977



The mode of commuting varies by settlement pattern. City dwellers are the highest percentage of public transportation users; suburbanites are the highest percentage of automobile users.

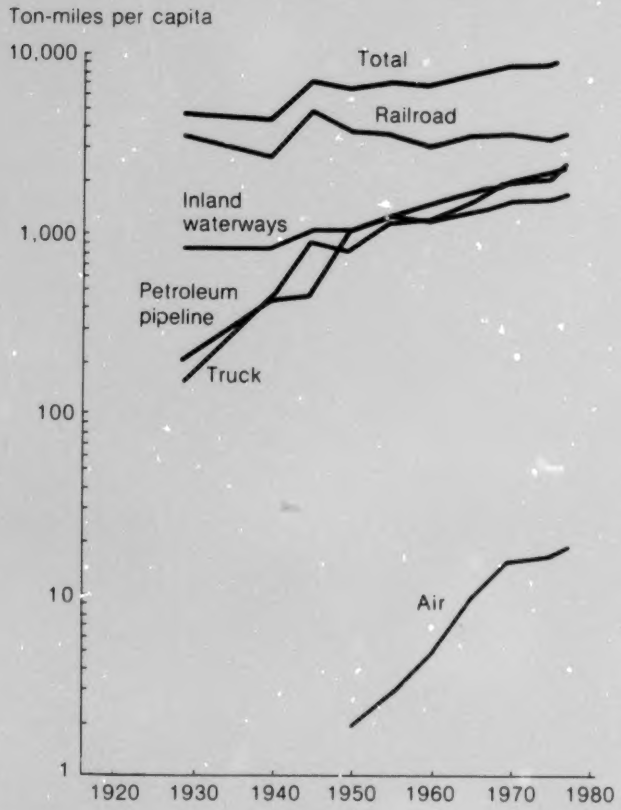
Commuting distance continues to grow. In 1963, less than a fourth of commuters traveled 10 or more miles to work. In 1976, more than a third commuted 10 or more miles to work, many on the Interstate Highway System. As a result, the commuting boundaries around major metropolitan areas are continuing to move outward.

4-7
Intercity passenger travel, 1929–1977



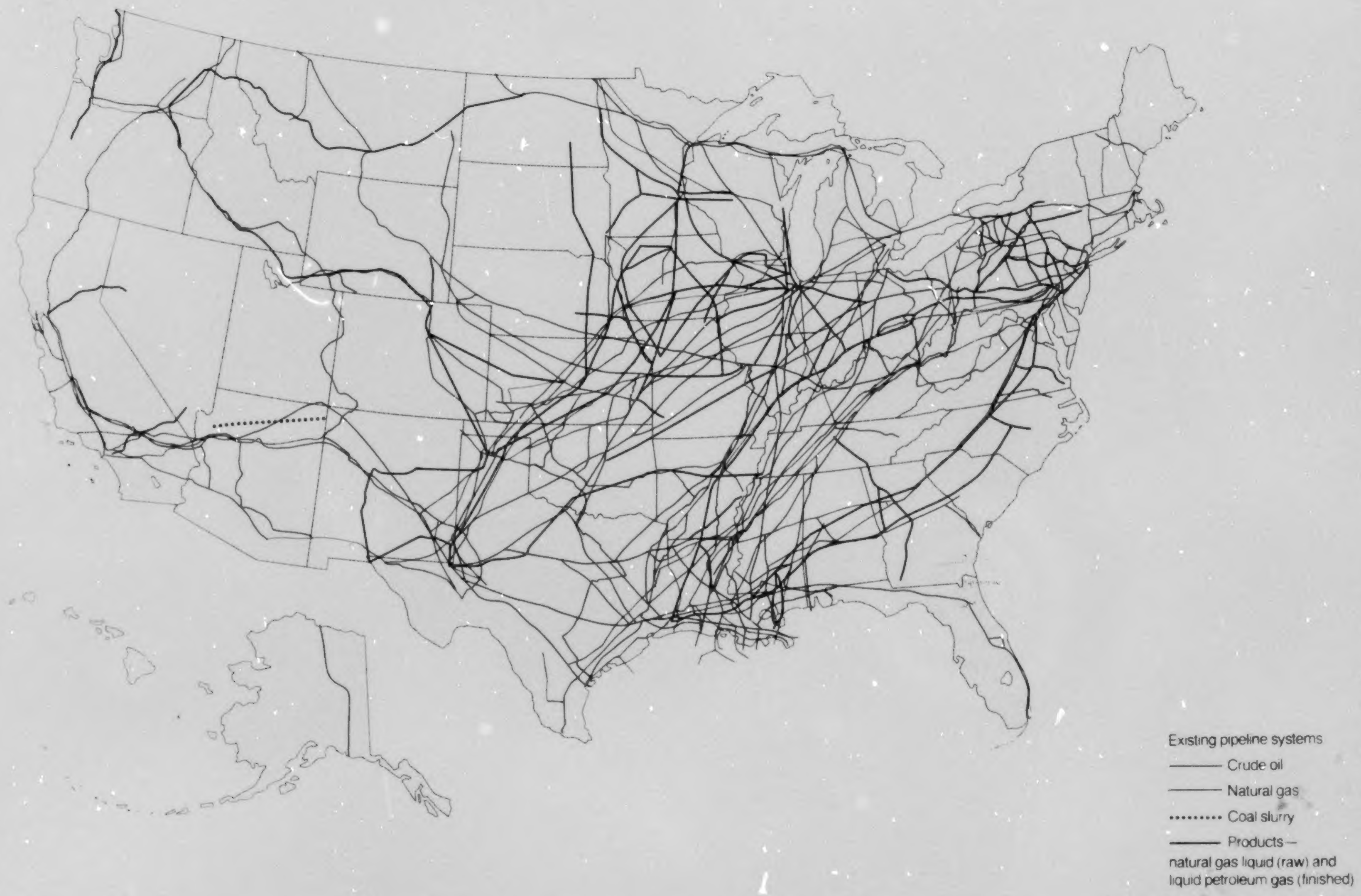
Intercity passenger travel is also dominated by the automobile. Of all transportation modes, only the railroad has declined sharply. It now provides roughly a fourth the number of passenger-miles per capita as it did in 1950.

4-8
Intercity freight transportation, 1929–1977



In 1977, 10,775 ton-miles of freight were transported between cities for each person in the country, more than double that in 1929. (A ton-mile represents one ton of goods transported one mile.) Railroads and barge lines once carried almost all freight between cities. Most bulk items and raw materials are now carried by rail, pipelines, and barges. Railroads and trucks carry finished manufactured products. Air transport is used primarily for light and highly perishable goods. These systems are often interconnected, and they use standard-size containers to reduce storage and handling and to speed delivery.

4-9
Major pipelines, 1975


Existing pipeline systems
Crude oil
Natural gas
Coal slurry
Products — natural gas liquid (raw) and liquid petroleum gas (finished)

121 118

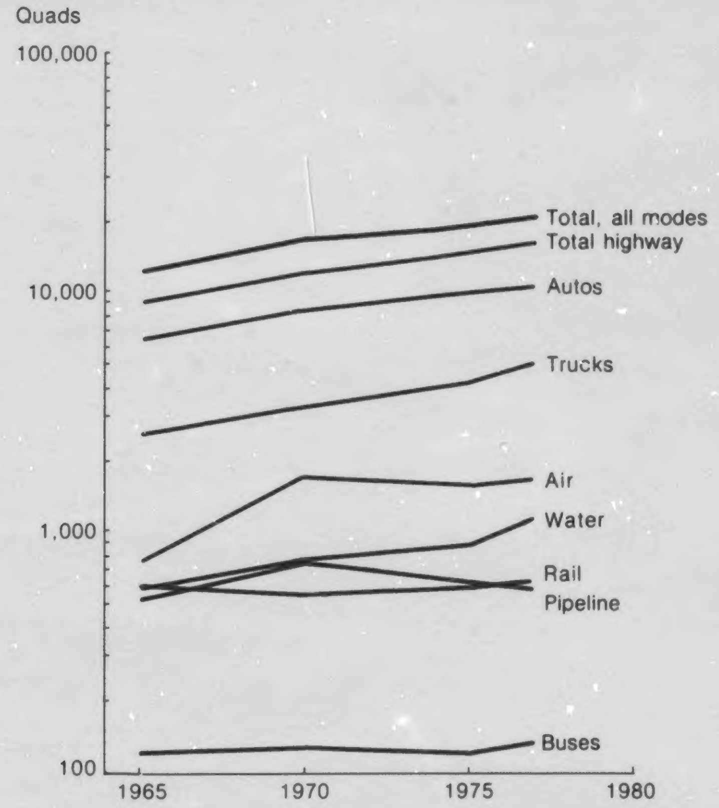
119uS1

The networks that are growing most rapidly are those for special uses. The most important special use is for energy—the miles and miles of pipelines and high-tension transmission lines that cross the nation, and the waterways and port facilities that receive and transmit crude oil, natural gas, and petroleum products.

The addition of coal slurry pipelines is now being considered. They use water to carry finely ground coal from mining areas to the places of use. In 1979, 273 miles were in operation. Most of this coal is used to generate electricity.

All energy networks require extensive rights-of-way and, for coal slurries, vast amounts of water as well. The average mile of oil and gas pipeline requires 12 acres of right-of-way for construction and 3 acres for maintenance.

4-10
Energy consumption, by mode of transportation, 1965–1977



Transportation—freight and passenger—uses 26% of all energy consumed in the United States. The highway sector consumes the largest portion—15.1 quads, equal to 79% of that used for all transportation.

☐ The quad is a measure of energy. One quad is the equivalent of 15.8 billion barrels of oil. It equals one quadrillion British thermal units (Btu). One Btu is the amount of heat required to raise the temperature of one pound of water 1° F at or near its point of maximum density, 39.2° F.

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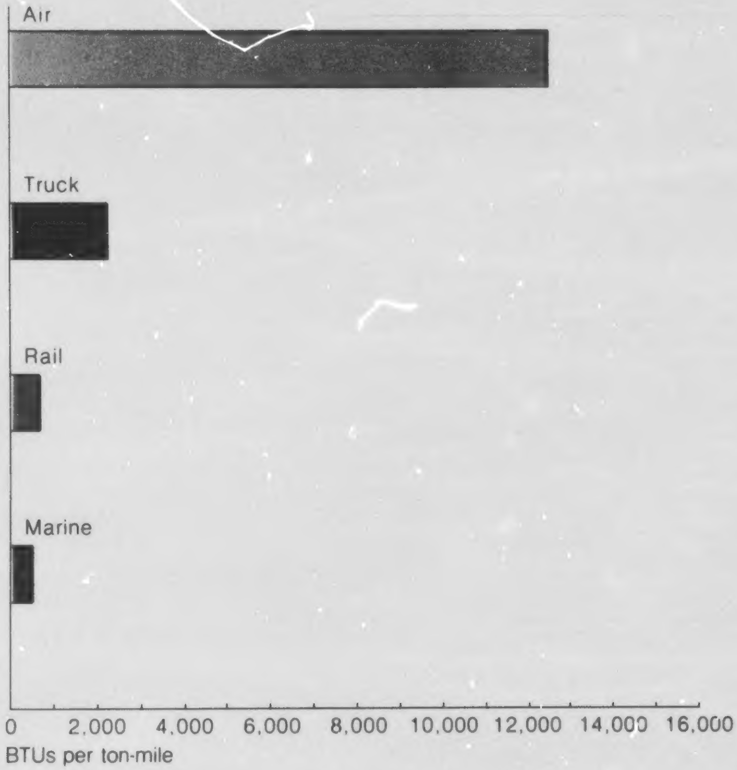
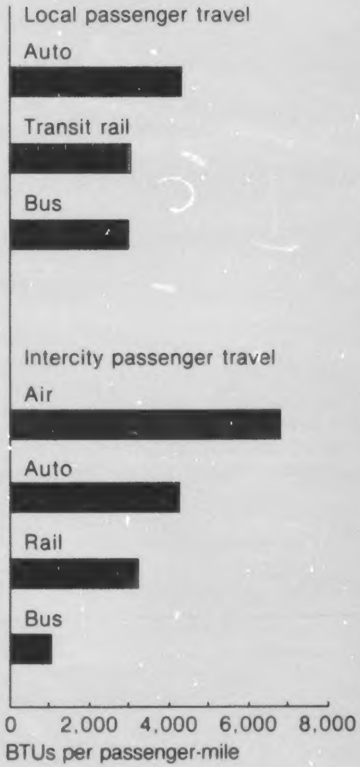
4-11
Energy intensity for freight transportation, 1976



Energy requirements for transportation depend, among other factors, on the type of vehicle, its speed and condition, load, and length of trip.

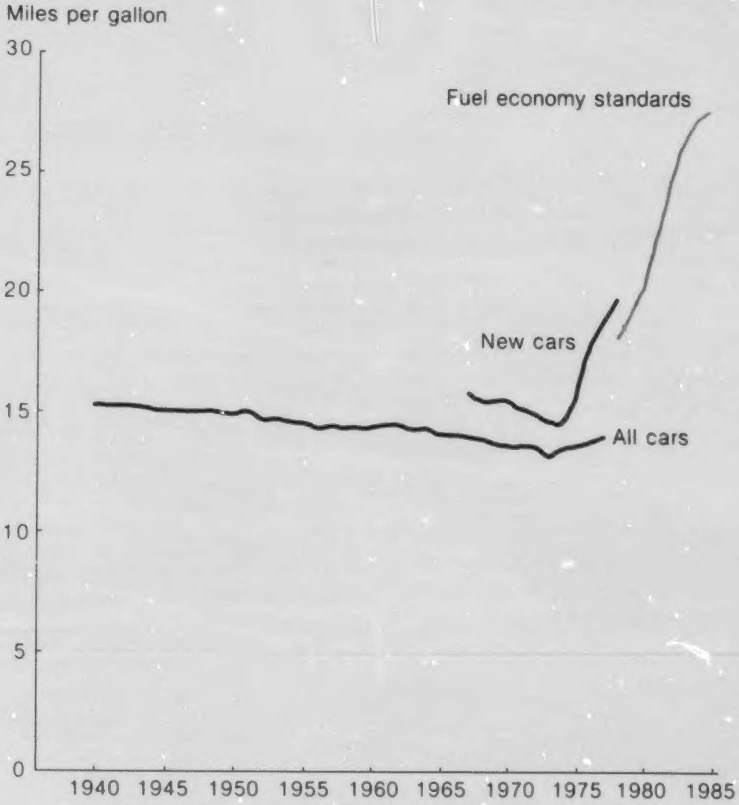
Because of the large loads and long distances traveled, water transport is the most energy efficient of the four major modes used to transport freight.

4-12
Energy intensity for local and intercity passenger travel, 1976



For local passenger travel, bus and rail transit use about the same amount of energy—3,000 Btu per passenger-mile. The automobile uses 4,300 Btu per passenger-mile.

4-13
Automobile fuel economy and standards, 1940–1985



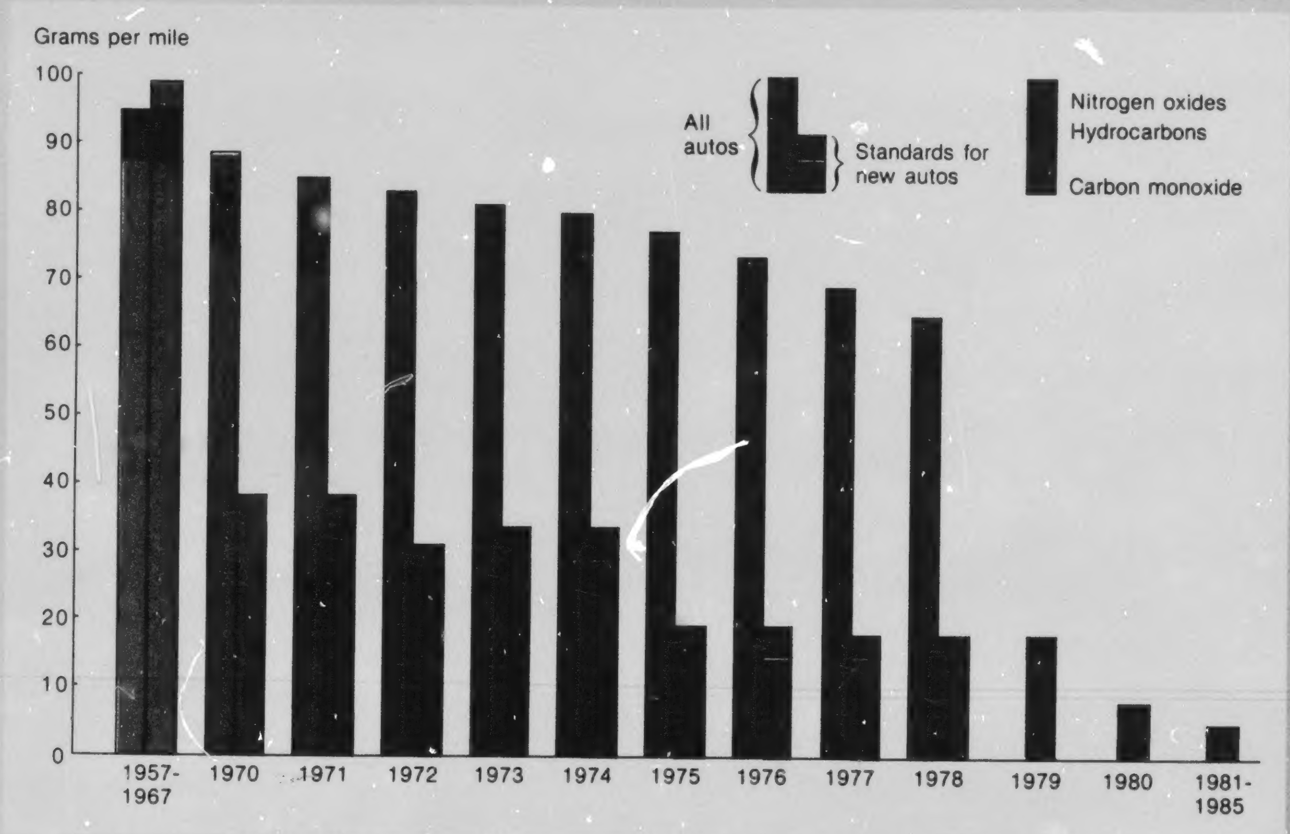
Fuel economy for new automobiles has improved in the past 5 years, and it will continue to improve if Federal fuel economy standards of 27.5 miles per gallon for new autos are reached by 1985. Average fuel economy for the entire fleet will not improve as rapidly because many large, fuel-inefficient vehicles are still on the road.

Increased efficiency is a function of motor vehicle design, lighter weight automobiles, and lower horsepower. Overall efficiency depends on how the cars are driven, emissions control and safety equipment, upkeep, passenger load, road surface, and other factors.

123

4-14

Automobile emissions and standards, 1957–1985



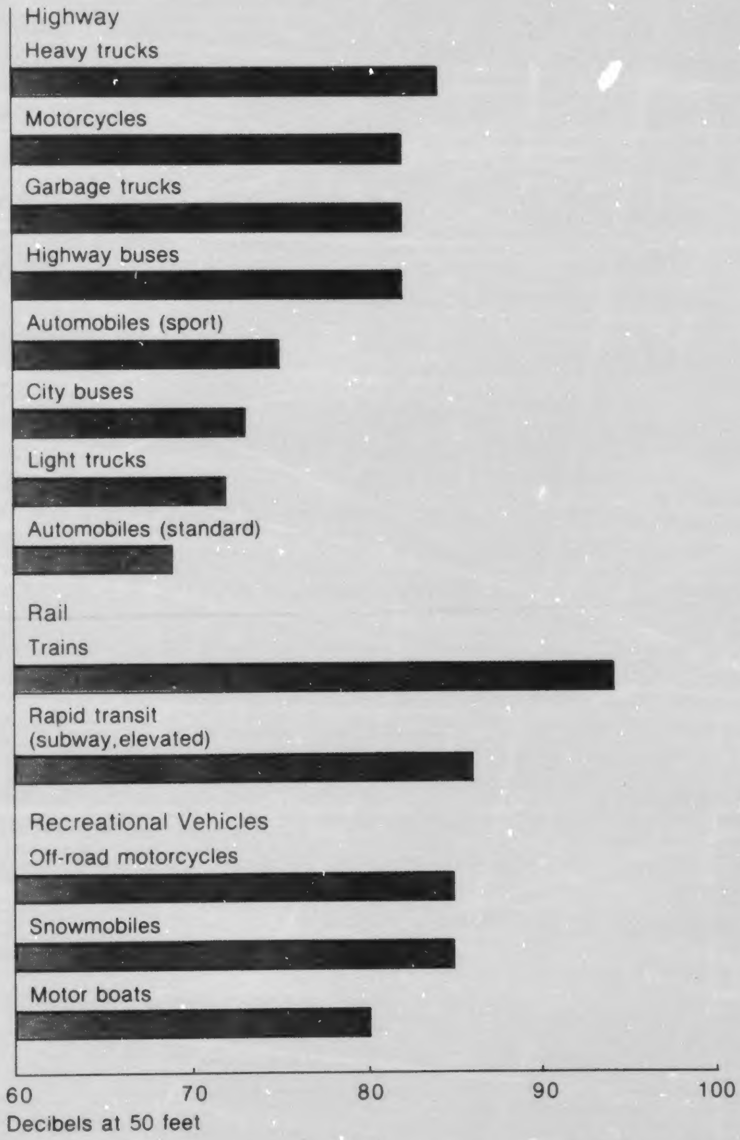
Transportation vehicles are major polluters. In 1977, they produced 83% of the carbon monoxide, 41% of the hydrocarbons, and 40% of the nitrogen oxides emitted into the atmosphere. These emissions cause serious health problems and affect plants and wildlife along rights-of-way. When hydrocarbons and nitrogen oxides are mixed with sunlight, they create ozone and other chemical oxidants that aggravate respiratory illnesses and are a major eye irritant.

Automobiles are by far the worst polluters, but emissions are decreasing. For the average auto, the amount was reduced to two-thirds the 1957–1967 level. For the latest year-model, the reduction was over 80%. There will be an additional 70% reduction in latest year-model emissions if Federal standards for 1985 are met.

124

125

4-15
Noise levels of surface transportation vehicles, 1971



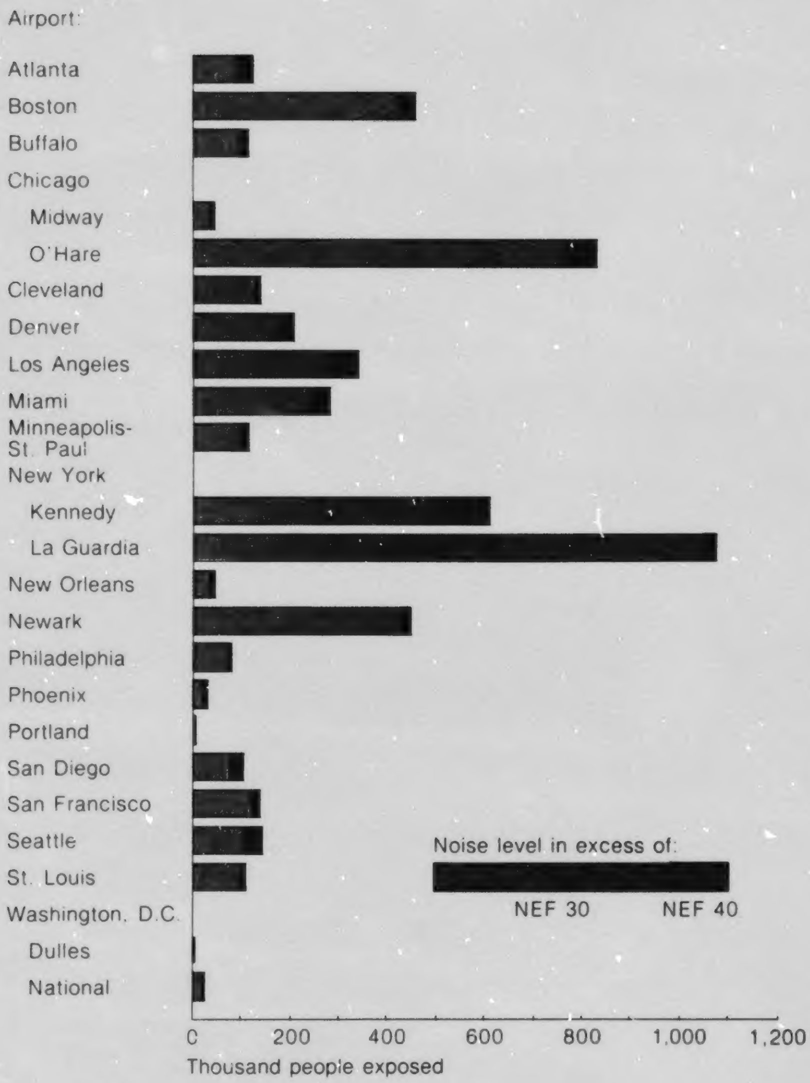
Surface vehicles, particularly trains, heavy-duty trucks, motorcycles, and intercity buses, are noisy. They are the main source of noise outside the home and workplace. An estimated 13.5 million people are exposed to outdoor noise from transportation or recreation vehicles at a level high enough to risk permanent damage to hearing.

The long-term health effects of excessive noise are well established. When the highly specialized cells needed for hearing are exposed to excessive noise, they are destroyed and some hearing is lost. The damage is irreversible.

Noise is measured in decibels (dB), which are an indirect measure of sound pressure. Noise levels of 75 dB or higher for an 8-hour period are considered harmful. An increase of 10 dB means that loudness has apparently doubled; an increase of 20 dB would quadruple apparent loudness.

☐ Each vehicle is ranked according to the noise that it creates when moving, as measured from 50 feet away. Accelerating vehicles are much noiser.

4-16
Population exposed to noise at 23 major airports, 1972



For many, aircraft noise is a major disturbance. In 1972, an estimated 6.1 million people lived in areas exposed to aircraft noise in excess of NEF 30, a point at which people begin to complain to public authorities. Of the 6.1 million, 600,000 lived in areas where aircraft noise exceeds NEF 40.

As of January 1979, 40 airports had curfews on air traffic to reduce noise levels. Of the 40, 11 were major commercial airports (Baltimore-Washington, National, and Dulles in the Washington, D.C. area; Minneapolis-St. Paul, Minn.; Boston, Mass.; San Diego, Calif.; Buffalo, N.Y.; Charlotte, N.C.; Nashville, Tenn.; San Jose, Calif.; and Columbus, Ohio).

☐ NEF, noise exposure forecast, is the total aircraft-generated noise measured at locations near an airport during a typical 24 hours.

Sources and technical notes

4-1
Major transportation networks, 1925–1978

Roads, 1925–1970: *Historical statistics of the United States, colonial times to 1970,* U.S. Bureau of the Census (Washington: USGPO, 1975), p. 710. *Highway statistics, summary to 1975,* Federal Highway Administration (Washington: USGPO, 1977), p. 211. 1977: *Highway statistics 1977,* Federal Highway Administration (Washington: USGPO, 1979), p. 229.

National Interstate Highway System, 1956–1978: "Quarterly report on the Federal-aid highway program, December 31, 1978," U.S. Department of Transportation, Office of Assistant Secretary for Governmental and Public Affairs (news release, April 24, 1979, and previous issues).

Natural gas pipelines, 1960–1976: "Brief excerpts from *Gas Facts,*" American Gas Association (Arlington, Va., 1978), p. 7.

Petroleum pipelines, 1960–1976: *Statistical abstract of the United States: 1978,* U.S. Bureau of the Census (Washington: USGPO, 1978), table 1128, p. 665.

Railways, 1929–1977: *Yearbook of railroad facts,* Association of American Railroads (Washington, D.C., 1979), p. 46.

Airways and inland waterways, 1939–1976: *Transportation facts and trends* (14th ed.), Transportation Association of America (Washington, D.C., 1978), p. 31.

Heavy rail transit (subway), 1945–1975: "United States rapid transit systems," Bob Abrams, National Capital Transportation Agency (Washington, D.C., 1965). U.S. Department of Transportation, Urban Mass Transit Administration, unpublished data.

All data are in statute miles.

National Interstate Highway System data are miles open at end of year.

Pipeline data include natural gas transmission lines and petroleum trunk lines.

Railways include all line-haul railroads and exclude yard tracks and sidings; one mile of railroad may include two or more parallel tracks.

Airways, 1960–1976, includes jet routes.

Heavy rail transit data are route-miles, not miles of track, for Atlanta, Baltimore, Boston, Chicago, Cleveland, the District of Columbia, New York City, the Trans-Hudson Port Authority and the New Jersey-Pennsylvania Port Authority, Philadelphia, and San Francisco.

Inland waterways are commercially navigable.

4-2
Transportation vehicles, 1920–1978

Autos, trucks, and buses, 1920–1975: *Highway statistics, summary to 1975,* Federal Highway Administration (Washington: USGPO, 1977), table MV-200, p. 45. 1976–1977: *Highway statistics 1977,* Federal Highway Administration (Washington: USGPO, 1979), p. 62.

Bicycles, 1960–1970: *Bicycle transportation,* U.S. Environmental Protection Agency (Washington: USGPO, 1974), p. 49. 1975–1978: Bicycle Manufacturers Association, unpublished data.

Motorcycles, 1940: *Statistical abstract of the United States: 1976,* U.S. Bureau of the Census (Washington: USGPO, 1976), table 988, p. 593. 1950–1977: *Statistical abstract of the United States: 1978* (Washington: USGPO, 1978), table 1090, p. 649.

Railroad cars, 1929–1977: *Yearbook of railroad facts,* Association of American Railroads (Washington, D.C., 1979), pp. 48, 49, 52.

Civil aircraft, 1929–1955: *Historical statistics of the United States, colonial times to 1970,* U.S. Bureau of the Census (Washington: USGPO, 1975), p. 772. 1960–1976: *Statistical abstract of the United States: 1978,* U.S. Bureau of the Census (Washington: USGPO, 1978), table 1131, p. 669.

Recreational boats, 1973–1976: *Recreational boating in the continental United States in 1973 and 1976: The Nationwide Boating Survey,* U.S. Coast Guard (Washington: USGPO, 1978), pp. 21, 22.

Freight vessels, 1970–1976: *Transportation energy conservation data book* (3rd ed.), Oak Ridge National Laboratory (Oak Ridge, Tenn., 1979), p. 1-154.

Population: *Statistical abstract of the United States: 1978,* U.S. Bureau of the Census (Washington: USGPO, 1978), table 2, p. 6.

Autos, trucks, and buses include registered vehicles.

Motorcycles, 1940–1977, include registrations of publicly owned motorcycles and excludes military vehicles. The 1977 data are estimated.

Railroad cars include locomotives, freight cars, and passenger cars in service.

Civil aircraft, 1950–1976, includes active and inactive aircraft, gliders, dirigibles, balloons, and blimps.

Recreational boats, 1973–1976, include runabouts, rowboats, johnboats, sailboats, canoes, cabin cruisers, skiffs, dinghies, kayaks, rafts, houseboats, and other boats.

Freight vessels, 1970–1976, include towboats, tugs, and barges operated for freight transportation on U.S. waterways.

Population is the resident population.

4-3
Sales of specialized vehicles, 1961–1978

Motorcycles, 1972–1977: *1978 motorcycle statistical annual,* Motorcycle Industry Council (Washington, D.C., 1978), p. 12, and previous annual issues.

Snowmobiles: *An assessment of the snowmobile manufacturing industry and sport, 1978,* International Snowmobile Industry Association (Washington, D.C., 1978), appendix A, p. 47.

Recreational vehicles, 1961–1966: *Motor vehicle facts and figures 1976,* Motor Vehicle Manufacturers Association (Detroit, 1977), p. 27. 1967–1977: *Facts and trends 1977,* Recreational Vehicle Industry Association (Chantilly, Va., 1978), p. 4. 1978: *Marketing report,* Recreational Vehicle Industry Association (Chantilly, Va., 1979), p. 6.

Mopeds, 1975–1977: Moped Association of America, unpublished data. 1978: News release.

Motorcycles include wholesale shipments to dealers by Harley Davidson, Honda, Kawasaki, Suzuki, and Yamaha for on-highway, off-highway, and dual-purpose bikes.

Recreational vehicles include total shipments of travel trailers, truck campers, camping trailers, and motor homes, except for 1961–1964, when motor homes are excluded.

Snowmobiles include all North American retail sales. Year refers to model year; for example, 1978 data are for April 1977 through March 1978.

4-4
Local passenger travel, 1950–1975

U.S. Department of Transportation, Office of the Secretary, unpublished data, in *Environmental Quality—1977,* Council on Environmental Quality (Washington: USGPO, 1977), p. 321.

Autos include taxis and personal trucks.

4-5
Principal means of transportation to work, 1960–1977

1960–1970: *Residential energy uses,* U.S. Bureau of the Census (Washington: USGPO, 1977) current housing reports, series H-123, special reports, chart 6.

1974–1977: *Annual housing survey: 1977,* U.S. Bureau of the Census (Washington: USGPO, 1979), part A, p. 6, and previous annual issues.

Data are not strictly comparable. Data for 1960–1970 include all workers 14 years old and older; 1974–1977 data include heads of households only.

4-6
Principal means of transportation to work, by location, 1977

See 4-5.

4-7
Intercity passenger travel, 1929–1977

All modes, 1929: *National transportation trends and choices,* U.S. Department of Transportation (Washington: USGPO, 1977), p. 114. 1939–1959: *Transportation facts and trends* (13th ed.), Transportation Association of America (Washington, D.C., 1977), p. 18. All modes except air, 1960–1977: *Motor vehicle facts and figures 1978,* Motor Vehicle Manufacturers Association (Washington, D.C., 1978), p. 54.

Air, 1960–1977: *Transportation facts and trends* (14th ed.), Transportation Association of America (Washington, D.C., 1978), p. 18.

Population: *Statistical abstract of the United States: 1978,* U.S. Bureau of the Census (Washington: USGPO, 1978), table 2, p. 6.

All 1977 data are preliminary.

Autos and buses data include intracity portions of intercity trips and excludes rural-to-rural trips, strictly intracity trips with both origin and destination in the same city, local bus or transit movement, and nonrevenue school and government bus operation.

Railroad data include commuter travel.

Commercial aircraft, 1970–1977, includes Alaska and Hawaii.

Population is the resident population.

4-8
Intercity freight transportation, 1929–1977

1929: *National transportation trends and choices,* U.S. Department of Transportation (Washington: USGPO, 1977), p. 114.

1939–1977: *Transportation facts and trends* (14th ed.), Transportation Association of America (Washington, D.C., 1978), p. 8.

Data include both for-hire and private carriers and mail and express transportation as appropriate, except for railroads, 1969–1977.

4-9
Major pipelines, 1975

National transportation trends and choices, appendix—U.S. transportation atlas, U.S. Department of Transportation (Washington: USGPO, 1976).

4-10
Energy consumption, by mode of transportation, 1965–1977

Transportation energy conservation data book (3rd ed.), Oak Ridge National Laboratory (Oak Ridge, Tenn., 1979), ORNL-5493, p. 2-13.

Energy use for recreational boats, included in the total, is not disaggregated separately. One estimate for 1976 puts this figure at 0.38 quads per year.

Highway total includes civilian autos (passenger cars and taxis), motorcycles, buses (intercity, school, and local), and trucks.

Air includes general aviation and certified air carriers.

Water transport is estimated from fuel purchased domestically.

Rail includes local rail (heavy and light) and operating Class 1 railroads (passenger and freight).

Total for all modes includes gasoline used for other purposes than highway, water, and air transportation, such as for cleaning fluid, fire starters, lawn mowers, etc.

4-11
Energy intensity for freight transportation, 1976

See 4-10, p. 2-28.

The unit of measure is the number of Btu consumed per route-ton-mile. A route-ton-mile represents one ton of goods transported one route-mile. A route-mile is the distance traveled between two selected points, a distance that differs for transportation modes. For example, the distance traveled by air is shorter than that traveled by auto or rail, so that data are not strictly comparable among modes.

Data for pipelines are not available in a comparable form.

4-12
Energy intensity for local and intercity passenger travel, 1976

See 4-10, p. 2-28.

The unit of measure is the number of Btu consumed per route-passenger-mile traveled. A route-passenger-mile represents one passenger traveling one route-mile. (See 4-11.)

Data do not include energy used in construction and maintenance.

Disaggregated local and intercity auto passenger travel data are not available.

4-13
Automobile fuel economy and standards, 1940–1985

All cars: *Highway statistics 1977,* Federal Highway Administration (Washington: USGPO, 1979), table VM-1, p. 100, and previous annual issues. *Highway statistics, summary to 1965,* Federal Highway Administration (Washington: USGPO, 1967), table VM-201A, p. 42.

New cars: *Transportation energy conservation data book* (3rd ed.), Oak Ridge National Laboratory (Oak Ridge, Tenn., 1979), ORNL-5493, p. 2-29.

Data are not strictly comparable.

Data for all cars are based on the average number of miles traveled per gallon of fuel consumed.

Data for new cars are based on the 1975 Federal Test Procedure, which is weighted to take into account both city and highway driving.

New cars, 1967–1974 model years, production data were used; 1975–1978 model years, manufacturers' sales forecast data were used.

4-14
Automobile emissions and standards, 1957–1985

All autos, 1957–1967: *Statistical abstract of the United States: 1978,* U.S. Bureau of the Census (Washington: USGPO, 1978), table 360, p. 216. 1970–1978: U.S. Environmental Protection Agency, unpublished data.

New autos: *The costs of clean air, 1974,* U.S. Environmental Protection Agency (Washington, D.C., 1974), table 3-1, p. 111-4. *Automobile exhaust emission surveillance analysis of the fiscal year 1974 program,* U.S. Environmental Protection Agency (Ann Arbor, Mich., 1976), p. 12. *Environmental quality—1977.* Council on Environmental Quality (Washington: USGPO, 1977), p. 22. U.S. Department of Commerce, Bureau of Economic Analysis, unpublished data.

Emissions from all light-duty autos, 1970–1978, and from all new autos are measured by the 1975 Federal Test Procedure, which assumes an average speed of 19.6 miles per hour at 75° F.

1957–1974: Passenger cars and light-duty trucks with a gross vehicle weight of 6,000 pounds or less.

1975–1985: Passenger cars only.

Nitrogen oxides, 1957–1967: No estimates available.

4-15
Noise levels of surface transportation vehicles, 1971

Report to the President and Congress on noise, U.S. Environmental Protection Agency (Washington: USGPO, 1972), Sen. doc. 92-63, p. 2-77.

4-16
Population exposed to noise at 23 major airports, 1972

Aviation noise abatement policy, U.S. Department of Transportation, Office of the Secretary, and Federal Aviation Administration (Washington, D.C., 1976), p. 20.

Chapter 5

Material Use and Solid Wastes

In every industrial society, raw materials are extracted, refined, processed, and transformed into finished products. Along the way, these processes generate large quantities of wastes, particularly solid wastes.

Such wastes are inevitable byproducts of industry. But this raises questions about controlling the amounts and types of materials needed to produce goods, the amounts and types of wastes that will be created, and the ways in which they will be disposed.

The main question is whether the processes by which raw materials are refined, products made, and goods consumed can be modified to reduce waste without greatly modifying the Nation's standards of living. (U.S. residents produce roughly twice as much consumer solid waste as do people living in countries with comparable economies and standards of living.)

Still other questions relate to the amounts of waste that can be reused or recycled economically and to controlling the disposal of wastes, particularly hazardous wastes, in order to reduce damage to human health and the environment.

5-1

Flow of materials, products, and solid wastes, 1977

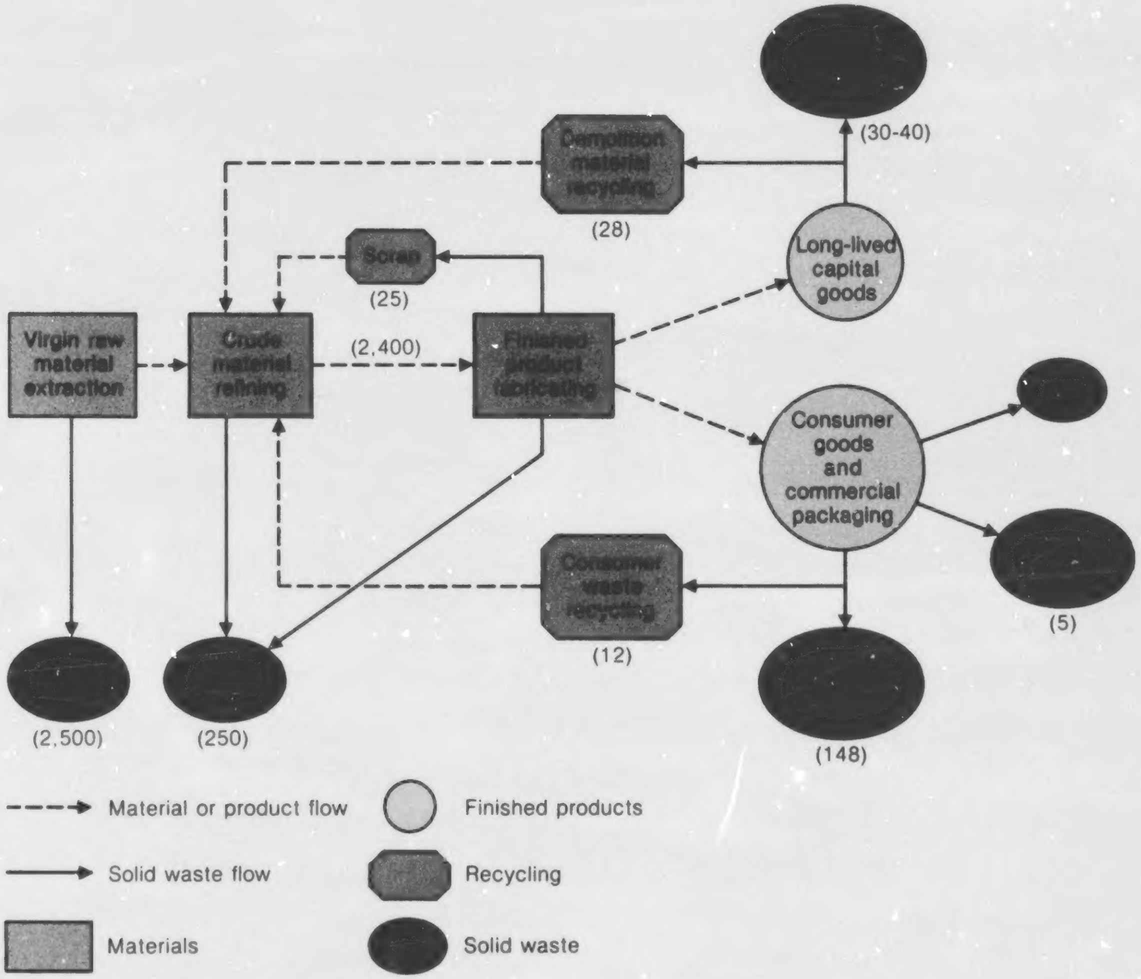
Each year billions of tons of virgin materials are extracted from mines, forests, and croplands. As a result, roughly 2.5 billion tons of solid wastes are generated in the form of mine tailings and spoils, forest residuals, and crop wastes.

The extracted material is purified, chemically treated, physically formed, or, at minimum, cleaned on the way to becoming a finished raw material—for example, from iron ore to steel, from saw logs to lumber, and from roundwood to wood pulp. This processing requires large amounts of water and energy, and it generates large volumes of liquid, gaseous, and solid wastes that are often among the most harmful to the environment and the most difficult to control. In excess of 2.4 billion tons of crude materials are then transformed into finished products each year.

The refining and fabricating processes generate an estimated 250 million tons of solid wastes per year. Most come from manufacturing, but large quantities also come from the transportation, communication, and utilities industries.

The finished products may be long-lived capital goods, such as homes, commercial buildings, and automobiles, or short-lived consumer goods. Sooner or later these goods and their packaging become waste as well.

(million tons per year)



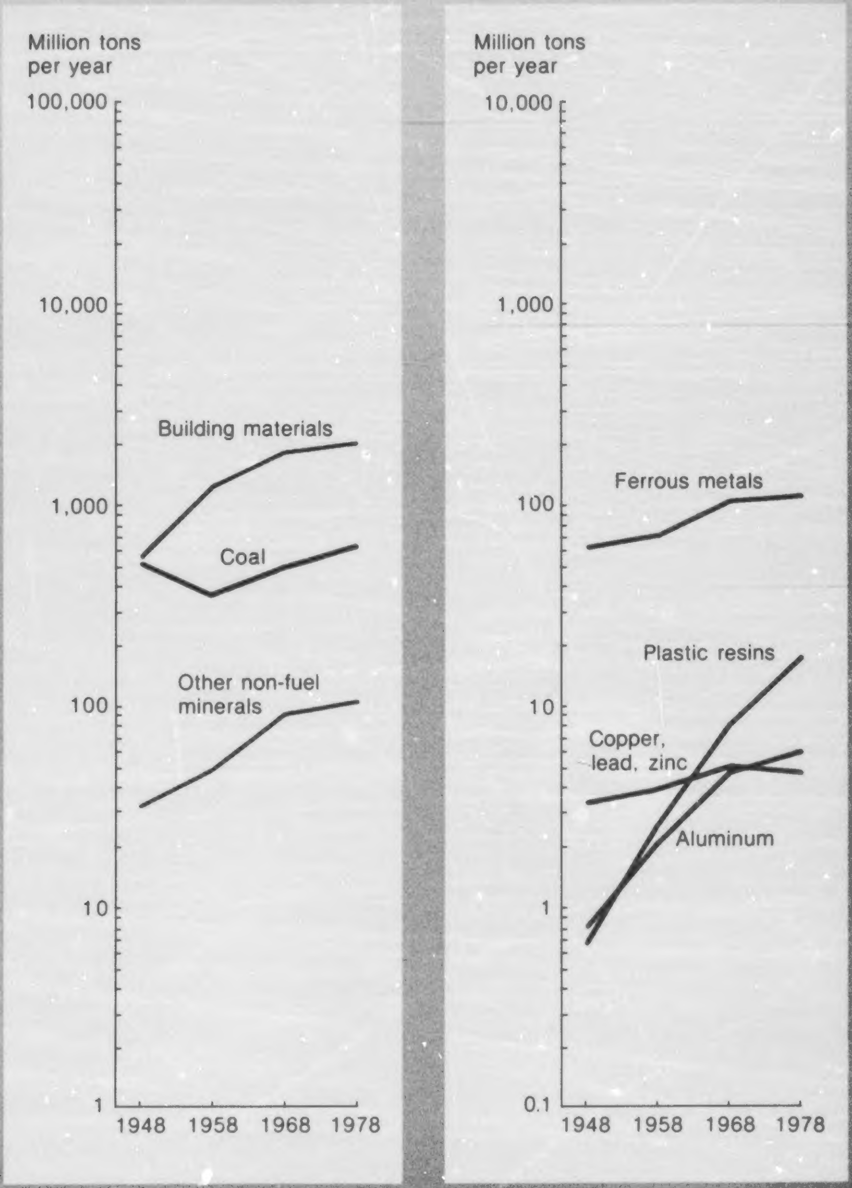
(30-40)
Demolition material recycling
(28)
Scrap
(25)
Long-lived capital goods
Virgin raw material extraction
Crude material refining
(2,400)
Finished product fabricating
Consumer goods and commercial packaging
Consumer waste recycling
(12)
(5)
(2,500)
(250)
(148)
Material or product flow
Solid waste flow
Materials
Finished products
Recycling
Solid waste

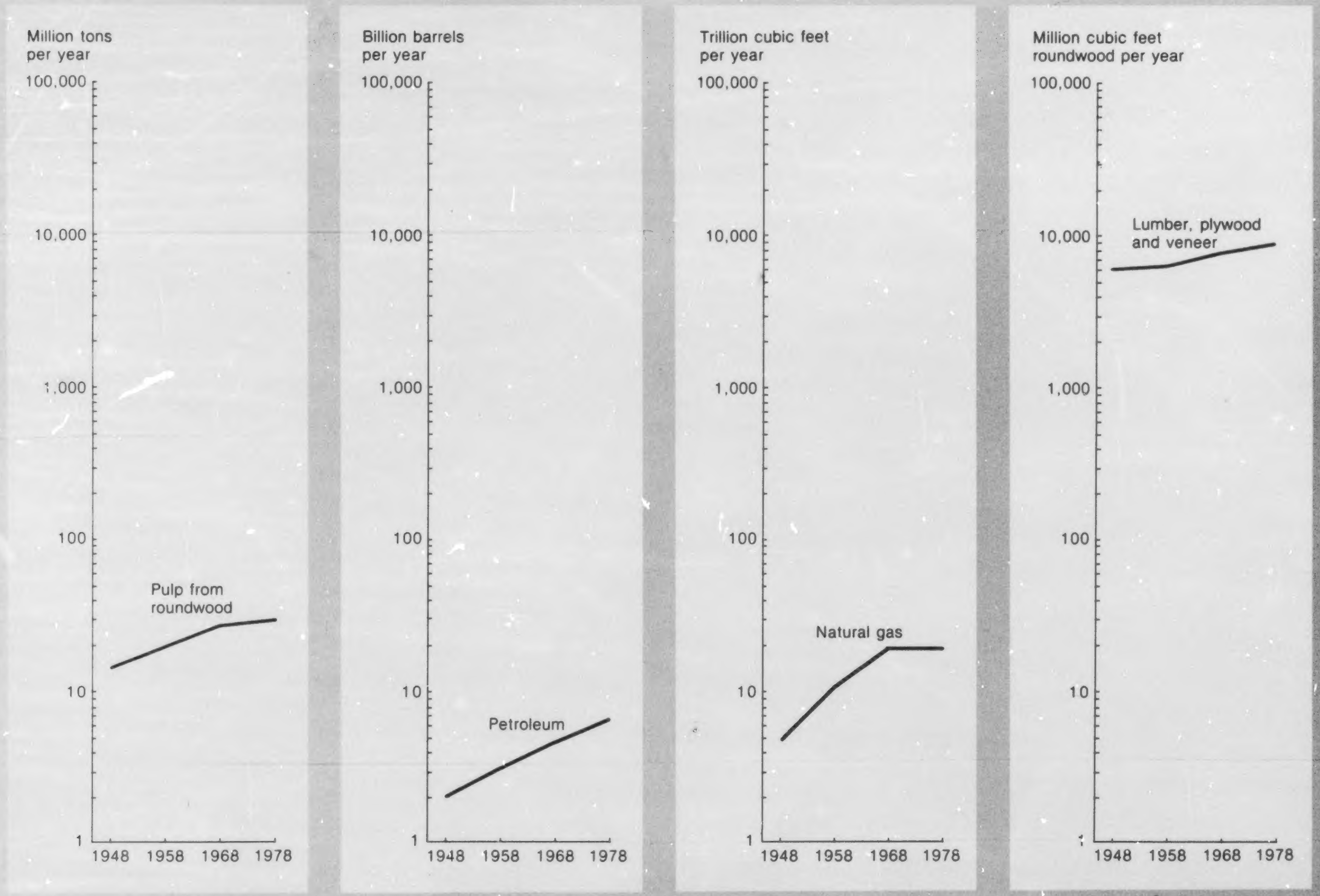
5-2

U.S. material consumption, 1948–1978

After substantial growth from 1948 to 1968, consumption in all major material groups except petroleum and plastic resins has slowed.

This slower growth may result in part from the slower growth of economic activity and of population. Measured in constant-dollar gross national product, the economy as a whole grew at a rate of 2.8% per year from 1969 to 1978, compared to 3.7% and 4.1% in previous decades. Population grew at an annual rate of 0.9% since 1968, compared to 1.5% for the two preceding decades.



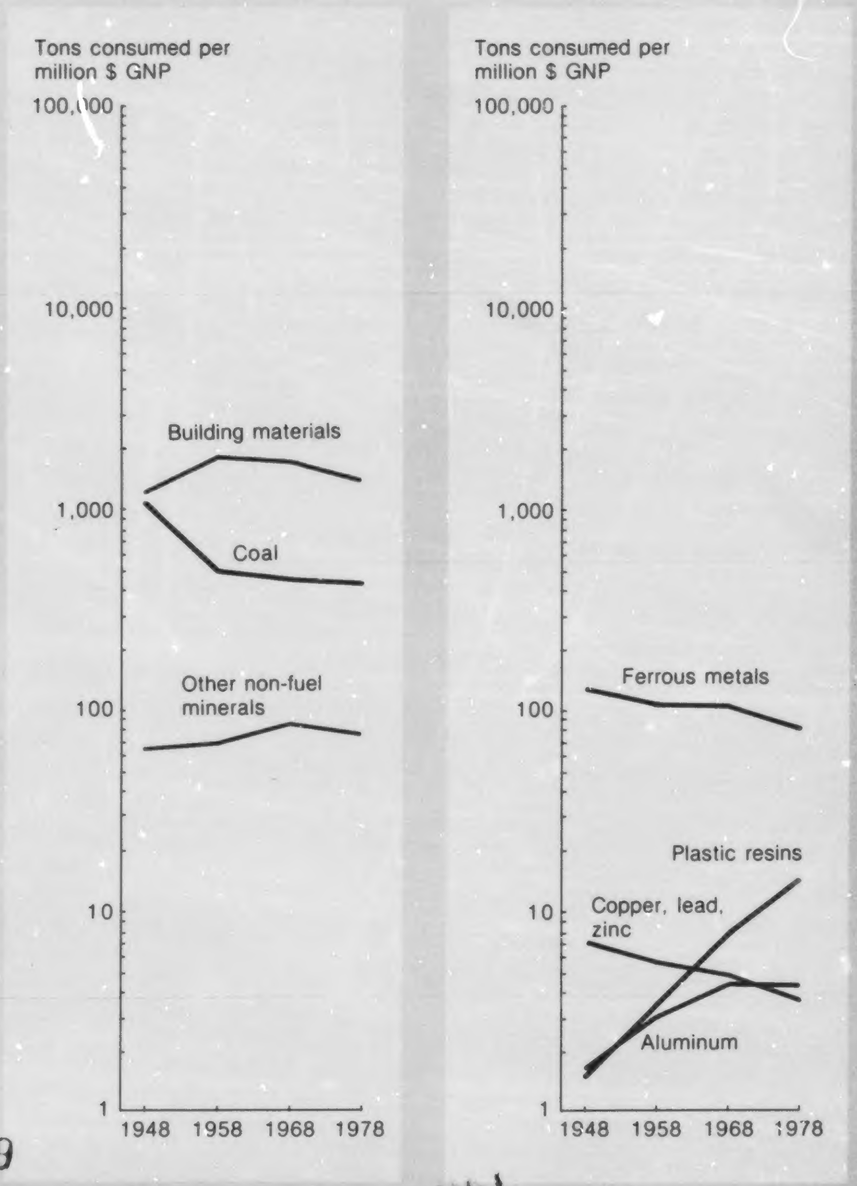

Million tons
per year
100,000
10,000
1,000
100
10
1
1948
1958
1968
1978
Pulp from
roundwood
Billion barrels
per year
100,000
10,000
1,000
100
10
1
1948
1958
1968
1978
Petroleum
Trillion cubic feet
per year
100,000
10,000
1,000
100
10
1
1948
1958
1968
1978
Natural gas
Million cubic feet
roundwood per year
100,000
10,000
1,000
100
10
1
1948
1958
1968
1978
Lumber, plywood
and veneer

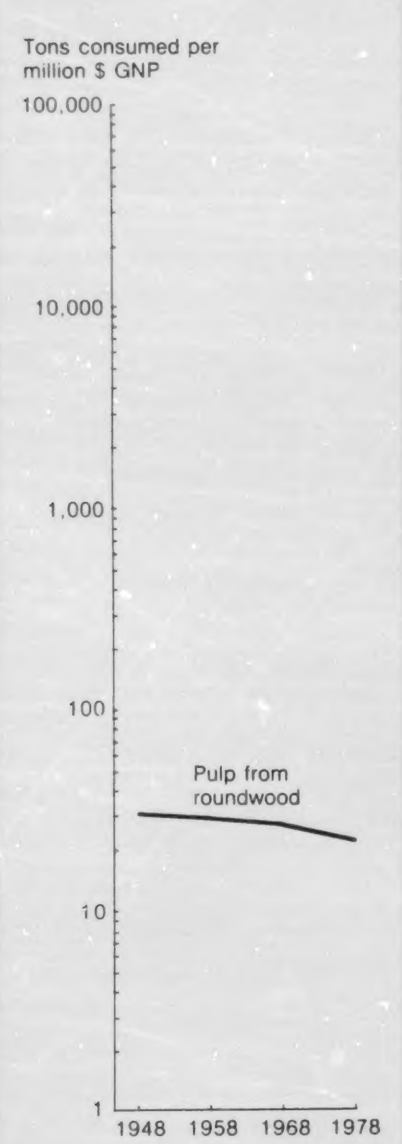
5-3

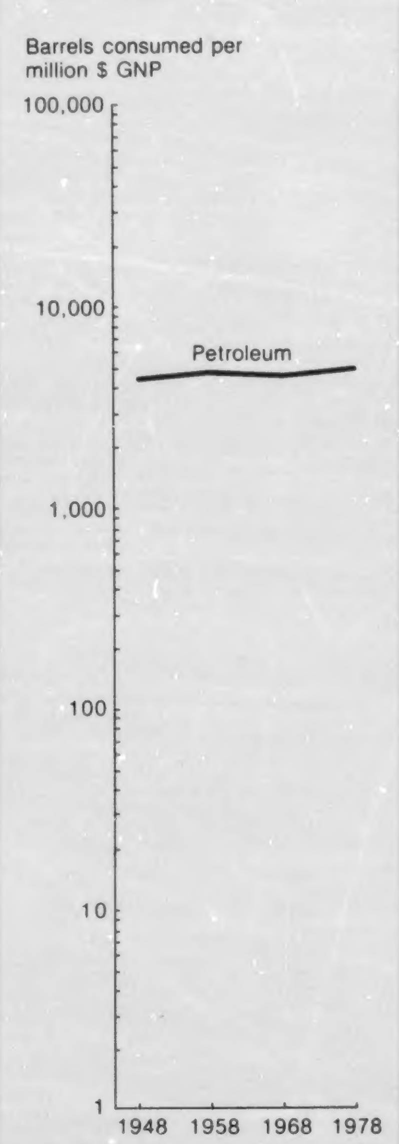
U.S. material consumption in relation to gross national product, 1948–1978

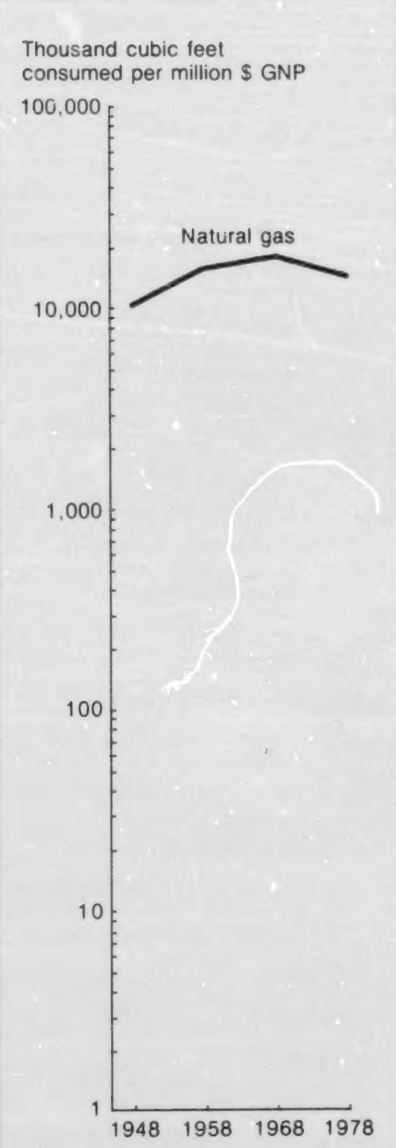
For most raw materials, there has been a continuing decrease in the quantity consumed per million dollars of GNP.

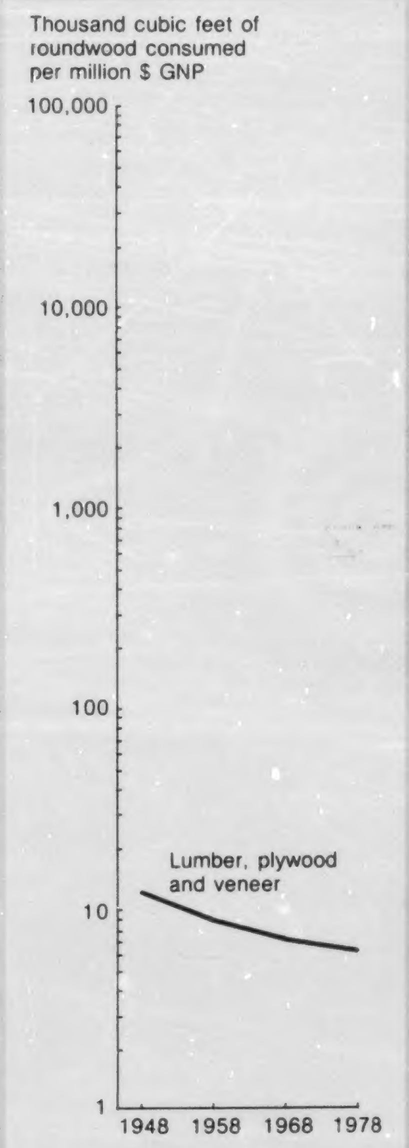
☐ Million dollars of GNP are shown in 1972 constant dollars.




Tons consumed per million $ GNP
100,000
10,000
1,000
100
10
1
Pulp from roundwood
1948
1958
1968
1978


Barrels consumed per million $ GNP
100,000
10,000
1,000
100
10
1
Petroleum
1948
1958
1968
1978


Thousand cubic feet consumed per million $ GNP
100,000
10,000
1,000
100
10
1
Natural gas
1948
1958
1968
1978

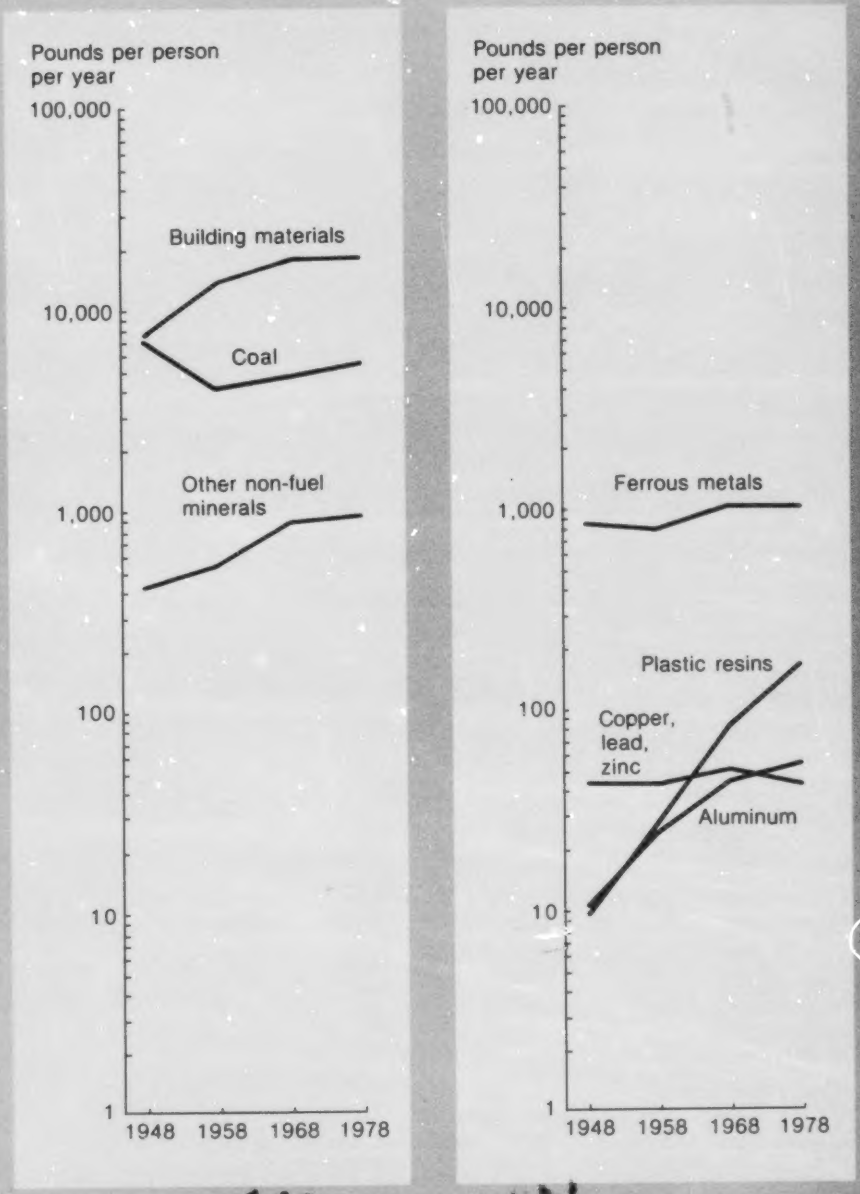

Thousand cubic feet of roundwood consumed per million $ GNP
100,000
10,000
1,000
100
10
1
Lumber, plywood and veneer
1948
1958
1968
1978

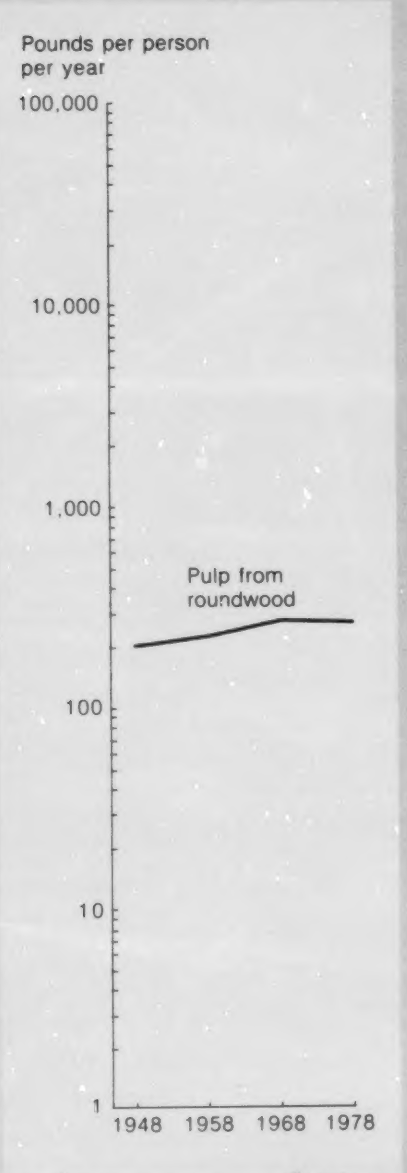
5-4

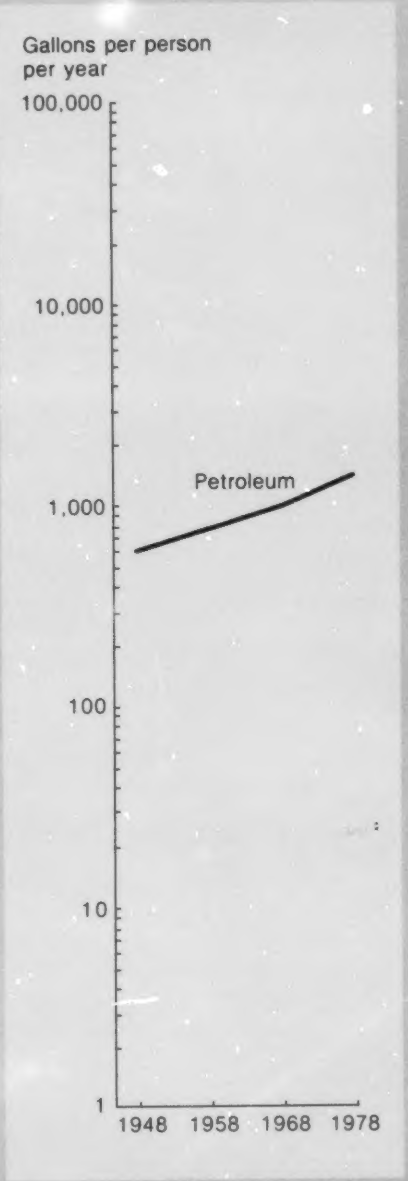
U.S. material consumption per capita, 1948–1978

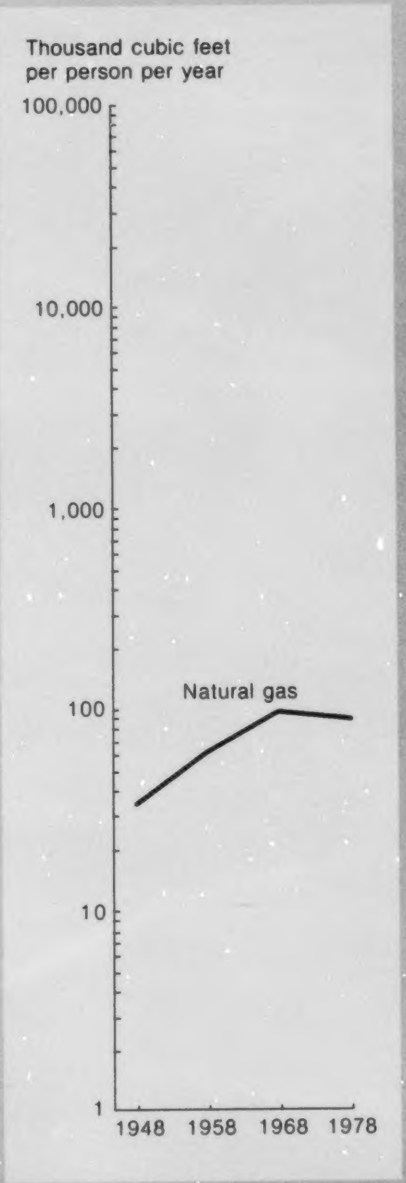
Between 1968 and 1978, per capita consumption of most basic raw materials almost stabilized. Petroleum consumption increased 30% from just over 1,000 to 1,307 gallons per person per year. Plastic resins consumption doubled, to 172 pounds per person per year.

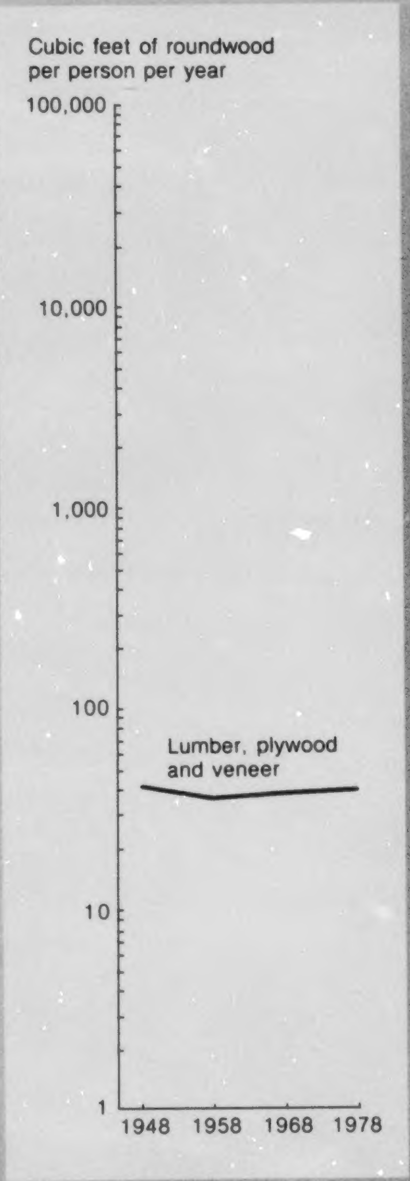
Relative to historical levels and to other countries, the United States continues to consume very large quantities of basic raw materials, but growth in consumption is slowing, and it may be declining relative to overall economic activity.




Pounds per person per year
100,000
10,000
1,000
100
10
1
Pulp from roundwood
1948
1958
1968
1978

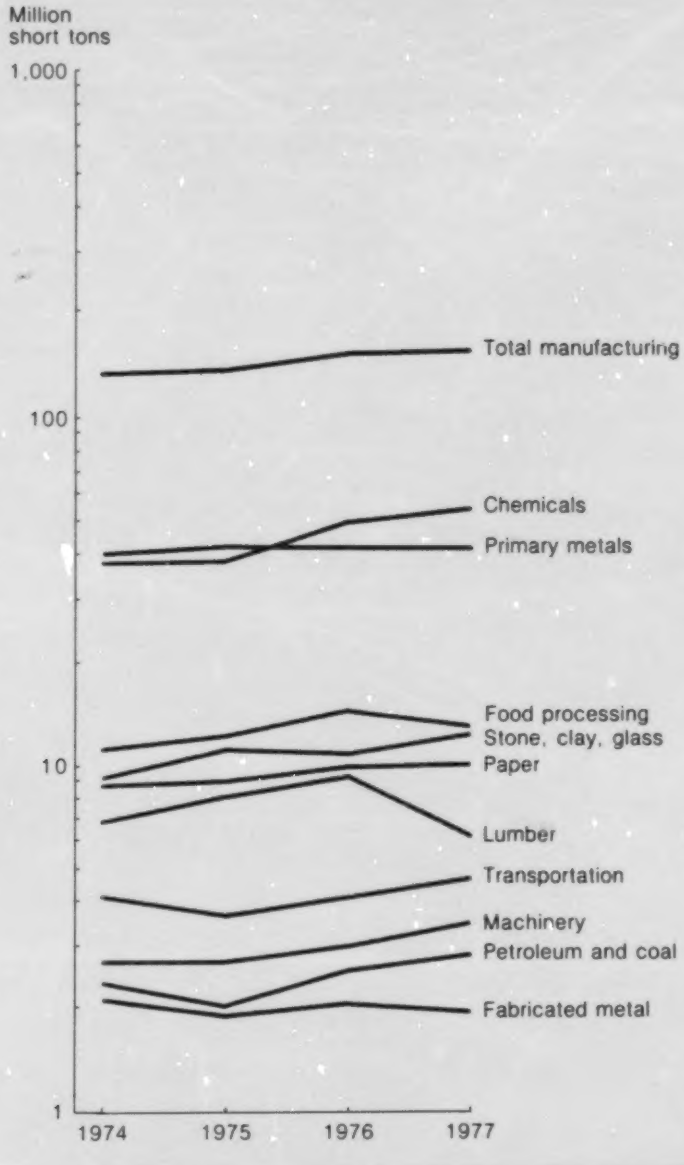

Gallons per person per year
100,000
10,000
1,000
100
10
1
Petroleum
1948
1958
1968
1978


Thousand cubic feet per person per year
100,000
10,000
1,000
100
10
1
Natural gas
1948
1958
1968
1978


Cubic feet of roundwood per person per year
100,000
10,000
1,000
100
10
1
Lumber, plywood and veneer
1948
1958
1968
1978

5-5

Solid wastes disposed of by manufacturing industries, 1974–1977



Most materials and goods eventually become wastes. They are generated at every stage in the production, use, and disposal of manufactured products.

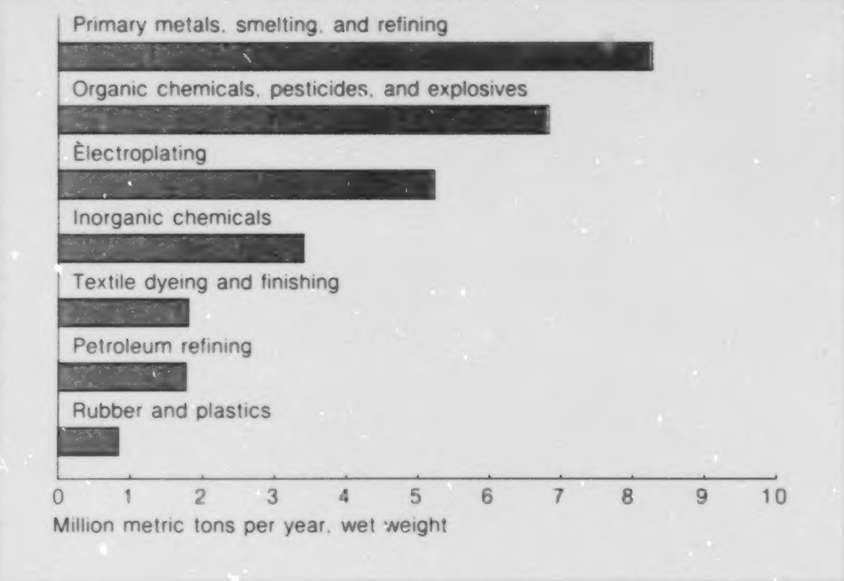
After the extractive industries, the largest amount of wastes comes from manufacturing. In 1977, these industries disposed of an estimated 160 million tons of solid wastes as sludge, slags, dusts, paper materials, and other organic and inorganic materials.

The chemical and primary metal industries produced the largest quantities. Much of the solid wastes generated by the chemical industry comes from processing phosphate fertilizer.

Most solid wastes from manufacturing are disposed of in landfills, open dumps, or impoundments, where pollutants often leach into or run off to ground and surface waters. Adverse environmental impacts can occur years after disposal.

5-6

Hazardous wastes generated, by selected industries, 1975

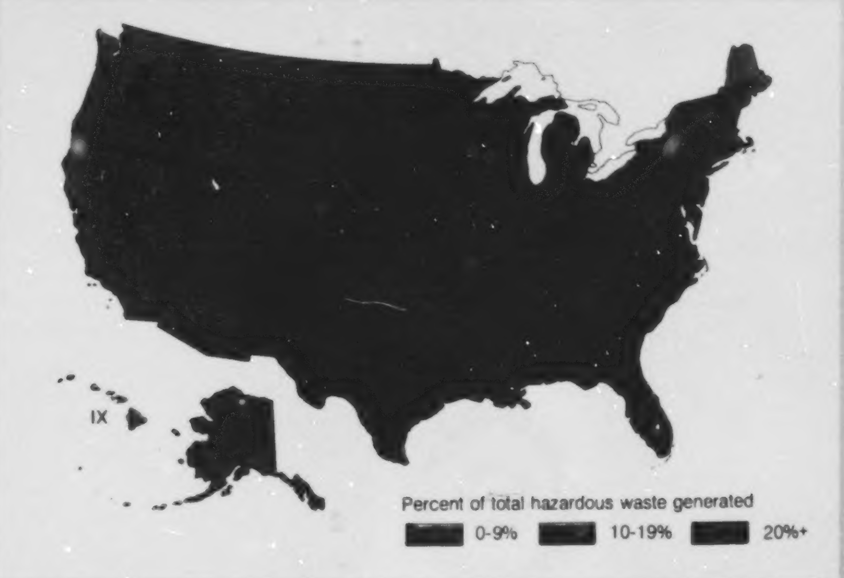


About 10% of all industrial wastes pose a possible threat to human health or living organisms. They include toxic chemicals, pesticides, heavy metals, oils, acids, caustics, flammables, explosives, and radioactive wastes. Most are liquids or semiliquids (sludge), but some are solids or gases. They are created by industries, farms, government installations (the Departments of Energy and Defense), hospitals, and laboratories.

☐ The industries listed in the bar chart account for approximately 60% of all industrial hazardous wastes.

5-7

Industrial hazardous wastes generated, by EPA region, 1975



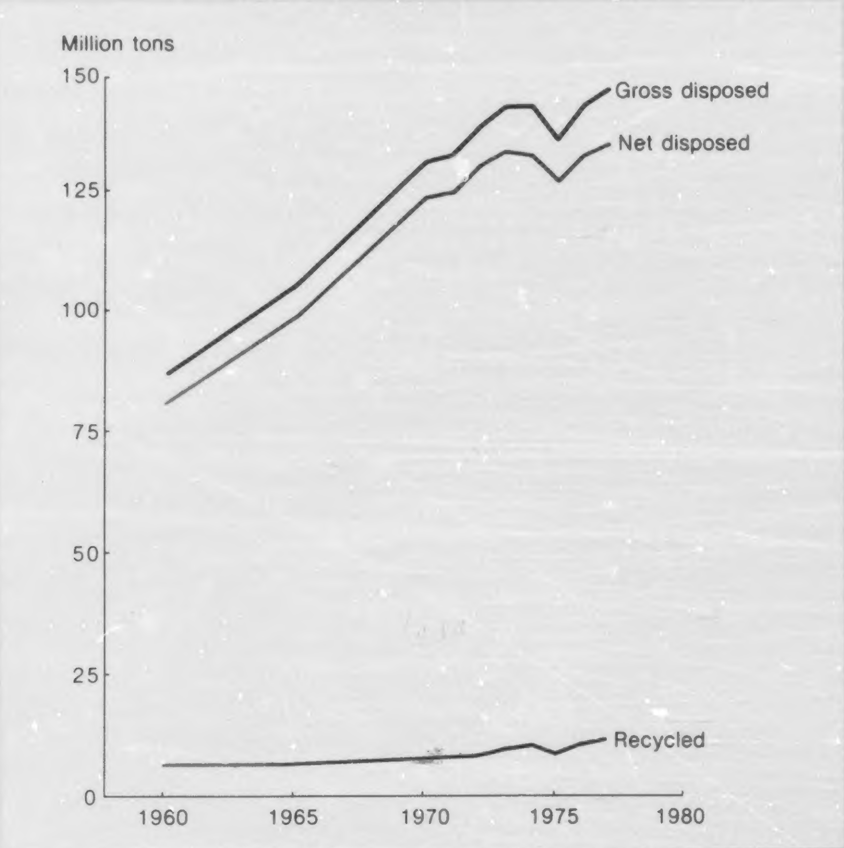
Potentially hazardous wastes are concentrated in a few regions of the country. EPA Region V has the largest amounts of hazardous wastes from six industries—batteries, primary metals, electroplating, special machinery, paints, and waste oil from refining; and Region IV was first in inorganic and organic chemicals, explosives and pesticides, and petroleum refining.

Although generated as byproducts of industrial processes, most hazardous wastes are disposed of away from the plants. EPA estimates the number of active hazardous waste disposal sites at over 19,000 and the total number of active and inactive sites at nearly 50,000.

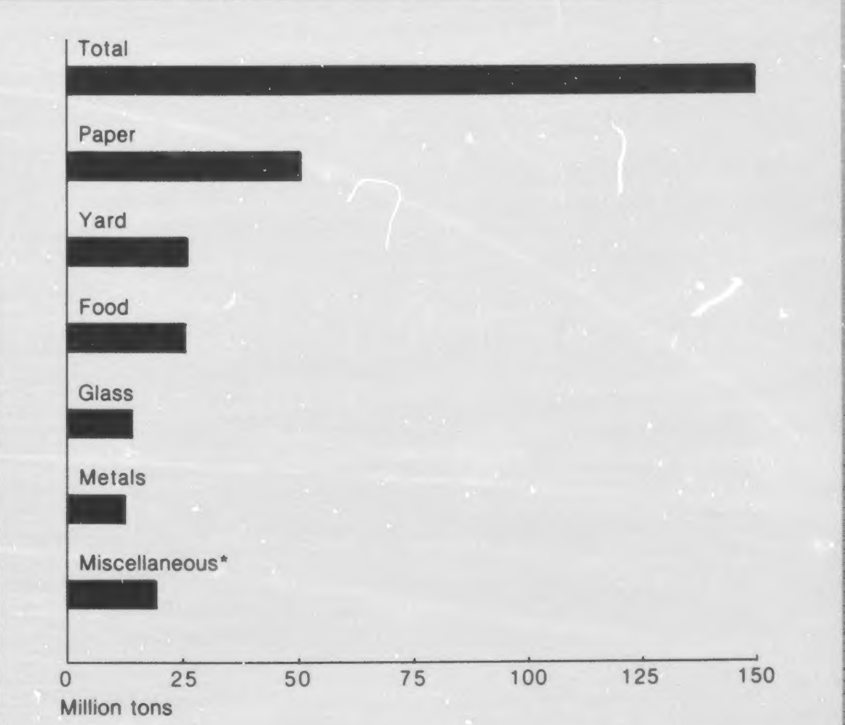
Numerous, often tragic, cases of damage to people, plants, and animals result from improper disposal of these wastes.

Most potentially hazardous wastes are disposed of on land. Only 10% are adequately disposed of, and 2% are recovered or recycled. Common disposal methods include lagooning in unlined surface impoundments, 50%; dump and landfilling, 30%; uncontrolled burning, 10%; and deep well injection, less than 10%—all methods that do not fully contain the wastes. The most common damage reported is contamination of ground and surface waters.

5-8
Consumer solid wastes disposed of and recycled, 1960–1978



5-9
Consumer solid wastes disposed of, by materials, 1978



*Miscellaneous includes plastics, rubber and leather, textiles, wood, and some inorganic wastes.

Consumer wastes are almost as voluminous as manufacturing wastes. Consumer solid wastes—the used residential and commercial products that end up as municipal trash and garbage—totaled 150 million tons in 1978, equal to about 3.7 pounds per person per day. By 1990, consumer solid wastes are projected to grow to 196 million tons per year, which is 4.4 pounds per person per day. (The 1975 decrease is a result of the recession and does not necessarily indicate a long-term trend.)

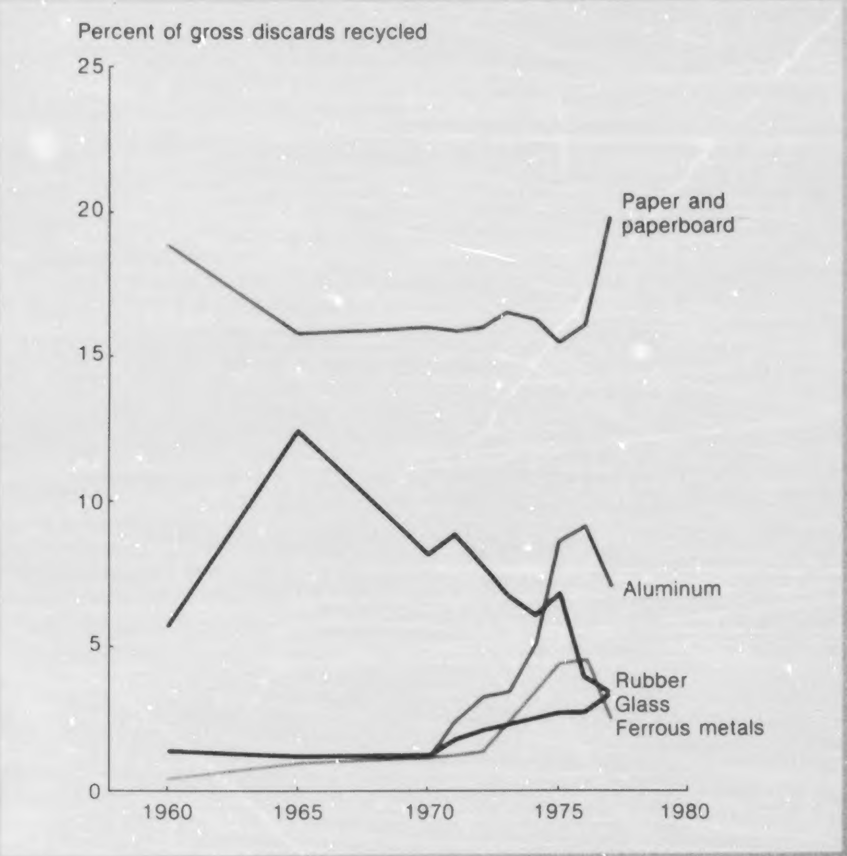
The wastes recovered for productive uses are only 8% (12 million tons) of all discards.

Consumer solid wastes are disposed of across the Nation in 16,000 landfills, 200 incinerators, thousands of open dumps, and as litter everywhere. About 8% are incinerated.

Paper is the largest category of consumer solid wastes, followed by yard wastes, food, glass, and metals.

In the past 25 years, changes have occurred in the composition of solid wastes disposed of. The increases are in paper, aluminum, packaging material, plastics, nonreturnable beverage containers, and collected yard wastes. The decreases are in food wastes and in coal and wood ashes.

5-10
Recycled consumer solid wastes, by material, 1960–1978



Only a small percentage of consumer wastes is recycled. Wastepaper accounts for more than 84% of it. The rate of recycling for wastepaper (more than 15%) is higher than that for any other waste.

Aluminum recycling has been growing because of the number of aluminum beverage cans made from recycled material. In 1978, more than a fourth of these cans were recycled.

Sources and technical notes

5-1
Flow of materials, products, and solid wastes, 1977

Adapted from *Choices for conservation*, Resource Conservation Committee (Washington: USGPO, 1980), fig. 1, p. 7.

Resource recovery refers to a productive use of material that would otherwise be disposed of as waste. It encompasses recycling, material conversion, and energy recovery. The most common process is recycling, the reprocessing of wastes to recover the original raw material. For example, steel is recovered from tin cans and fiber is recovered from wastepaper. Reuse differs in that a product is reused in the same form; for example, glass bottles. In material conversion, the waste is used in a different form, such as in road-paving material from auto tires. Energy recovery refers to obtaining heat from organic wastes, as in refuse-derived fuel incinerators.

5-2
U.S. material consumption, 1948-1978

See 5-1, table 3, p. 28.

Estimates for the raw materials consumed account for more than 95% of all material use by weight. Only large volume materials have been included. Synthetic organics other than plastics and many metals were omitted.

5-3
U.S. material consumption in relation to gross national product, 1948-1978

See 5-1, table 4, p. 29.

5-4
U.S. material consumption per capita, 1948-1978

See 5-1, table 4, p. 29.

5-5
Solid wastes disposed of by manufacturing industries, 1974-1977

Pollution abatement costs and expenditures, 1977, U.S. Bureau of the Census (Washington: USGPO, 1979), current industrial reports MA-200(77)-2, table 4a, and previous annual issues.

Data include solid wastes properly disposed of by means acceptable to local, State, and Federal authorities. Recovered materials are excluded. The aggregated data are composed partly of wet weight and partly of dry weight figures. Wet weight, which includes the water content, is the tonnage actually handled and charged for by the waste treatment industry.

The apparent decline in lumber wastes between 1976 and 1977 may reflect a change in survey samples rather than a change in the amount of solid wastes disposed of.

Sludge is the residue from scrubbers or after wastewater has been treated.

Dumps, landfills, sanitary landfills, and secured landfills are the four major types of solid waste land disposal sites that receive both municipal and industrial (including commercial) solid waste. In its *Report to Congress: Waste disposal practices and their effects on ground water* (Washington: USGPO, 1977), p. 145, EPA has defined the four major types of sites as follows:

"A dump is an uncovered land disposal site where solid and/or liquid wastes are deposited with little or no regard for pollution control or aesthetics. Dumps are susceptible to open burning and are exposed to the elements, vectors, and scavengers.

"A landfill is a land disposal site located without regard to possible effects on water resources, but which employs intermittent or daily cover to minimize scavenger, aesthetic, vector, and air pollution problems.

"A sanitary landfill is a land disposal site that employs an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the solid wastes in thin layers, compacting the solid wastes to the smallest practical volume, and applying and compacting cover material at the end of each operating day.

"A secured landfill is a land disposal site that allows no hydraulic connection with natural waters, segregates the waste, has restricted access, and is continually monitored."

Leachate is formed from water percolating through solid wastes. Leachate from post-consumer solid wastes is a highly mineralized fluid containing chloride, iron, lead, copper, sodium, nitrate, and a variety of organic chemicals. Municipal sites generate about 90 billion gallons of leachate per year, most of it filtering into ground water. If manufacturing wastes are included, hazardous substances such as cyanide, cadmium, chromium, chlorinated hydrocarbons, and PCBs may be present in leachate.

5-6
Hazardous wastes generated, by selected industries, 1975

"USEPA's industry studies on hazardous waste management," presented at the National Conference on Hazardous Waste Management, San Francisco, February 1, 1977, table 3, p. 9.

Data on hazardous wastes by the manufacturing sector are not strictly comparable to the data on total manufacturing solid waste shown in 5-5.

EPA studied seven other industries: Special machinery, which generates 0.16 million metric tons per year; leather tanning, 0.15; paint and allied products, 0.10; pharmaceuticals, 0.07; waste oil re-refining, 0.06; electronic components, 0.04; batteries, 0.01.

Hazardous wastes can damage human health or living organisms because these wastes are lethal, nondegradable, or persistent. They can be biologically magnified. They can cause or tend to cause detrimental, cumulative effects.

EPA has defined potentially hazardous waste in terms of potential damage from improper land disposal. These damages include "ground water contamination via leachate; surface water contamination via runoff; air pollution via open burning, evaporation, sublimation, and wind erosion; poisoning via direct contact; poisoning via the food chain; and fire and explosion." ("The potential for national health and environmental damages from industrial residue disposal," E. C. Lazar, et al., in Proceedings of the National Conference on Disposal of Residues on Land, September 13-15, 1976, sponsored by the EPA Office of Solid Waste, p. 196.)

5-7
Industrial hazardous wastes generated, by EPA region, 1975

See 5-6, table 5, p. 13.

5-8
Consumer solid wastes disposed of and recycled, 1960-1978

1960-1970: "Post-consumer solid waste and resource recovery baseline," Franklin Associates, Ltd., prepared for the Resource Conservation Committee (Washington: EPA, 1979), table 1, p. 9.

1971-1976: Environmental Protection Agency, Office of Solid Waste, unpublished data.

1977-1978: Franklin Associates, Ltd., unpublished data prepared for the Committee.

Consumer solid wastes exclude wastewater treatment sludge (about 5 million tons, dry weight, per year), discarded autos and building demolition materials (30-40 million tons per year), street sweepings, and litter.

If food and yard wastes are excluded, the net waste disposed of by consumer residential and commercial sources in 1978 becomes 100 million tons.

5-9
Consumer solid wastes disposed of, by material, 1978

See 5-8.

5-10
Recycled consumer solid wastes, by material, 1960-1978

1960-1970: See 5-8, pp. 11, 21.

1971-1975: *Resource recovery and waste reduction: Fourth report to Congress*, EPA (Washington: USGPO, 1977), SW-600, table 6, p. 19.

1976: Environmental Protection Agency, unpublished data.

1977-1978: See 5-8.

Data for ferrous metals are highly inferential and preliminary.

Chapter 6

Toxic Substances

Because "toxic" is a relative term, it is not useful to classify all chemicals as toxic or nontoxic. Toxic effects depend not only on the composition and basic properties of a substance or mixture but also on the dosage, route and conditions of exposure, susceptibility of the organism exposed, and other factors.

In this discussion, toxic substances are chemicals or mixtures of chemicals, either synthetic or natural, that are poisonous to humans, plants, or animals under expected conditions of use and exposure. These substances include pesticides, some industrial chemicals, drugs, hazardous wastes, and radioactive materials.

Toxic substances can cause immediate poisoning, behavioral and other nervous system disorders, and other illnesses. Over time, exposure can lead to chronic ailments and disability and can affect the growth of cells, sometimes causing cancer, genetic damage, or mutation. Owing to their widespread distribution, use, and disposal, toxic substances pervade the environment.

Four kinds of toxic substances have been chosen to illustrate conditions and trends: pesticides, industrial chemicals, metals, and radioactive materials. The examples chosen are known to be damaging to wildlife and natural systems as well as people, and data are available on their production, use, distribution, and effects. Most have been studied in detail and are or were important commercially.

6-1
Selected toxic substances

A great deal has been discovered about how some well-known toxic substances move through the environment and influence the health of wildlife and humans. Many have been identified only after harm was apparent. Few substances are adequately tested for long-term toxicity before they are produced and used. Few are adequately monitored to ensure that concentrations remain below safe levels. And little is known about the cumulative and interactive effects on the health of living systems of so many of the toxic substances that are present in the environment.

Category	Original source	Past, present uses	Human health effects	Environmental effects
Pesticides				
Aldrin/dieldrin	Chemically manufactured	Insecticide	Tremors, convulsions, damage to kidneys, suspected carcinogen	Reproductive failure of birds and fish
DDT	Chemically manufactured	Insecticide	Tremors, degradation of central nervous system (CNS), suspected carcinogen	Reproductive failure of fish, eggshell thinning in birds
Parathion	Chemically manufactured	Insecticide	Acute toxicity	Kills wildlife
Toxaphene	Chemically manufactured	Insecticide	Chromosome change in female workers, suspected carcinogen	Accumulation in fish, inhibition of growth, damage to liver of fish
2,4-D	Chemically manufactured	Herbicide	Forms nitrosamines in intestinal tract	Reduces natural habitat
Industrial chemicals				
Acrylonitrile	Chemically manufactured	Plastic resin in pipes, textiles, appliances, until 1977 in plastic beverage bottles	Suspected carcinogen	Releases toxic chemical, hydrogen cyanide, when burned
Asbestos	Mining, milling	Brake linings, fireproofing, insulation, cement pipes, consumer products	Lung damage, lung cancer, stomach cancer	
Benzene	Petroleum refining	Gas additive, insecticides, arts and crafts supplies, detergents, moldings, fibers	Anemia, bone marrow damage, leukemia	
Phthalates	Chemically manufactured	Plasticizer (added to plastics, resins)	CNS damage	Accumulation in birds, eggshell thinning in birds, toxic to fish
Polychlorinated biphenyls (PCBs)	Chemically manufactured	Industrial fluids, capacitors, transformers, heat transfer fluids, plasticizers	Fatigue, vomiting, skin blemishes, abdominal pain, temporary blindness, still births, suspected carcinogen	Liver damage in mammals, kidney damage, eggshell thinning in birds, suspected reproductive failure in fish
Vinyl chloride	Chemically manufactured	Plastics, polyvinyl chloride	Liver damage, birth anomalies, liver, respiratory, brain, lymph cancers, circulatory, bone damages	

155

156

Category	Original source	Past, present uses	Human health effects	Environmental effects
Metals				
Arsenic	Mining, ore-smelting	Glass, pesticides, hardening agent for copper, lead and alloys	Vomiting; poisoning; degeneration of liver and kidneys; lung, liver, lymph, skin cancers	Persists in soil, toxic to legume crops
Cadmium	Mining, zinc-smelting, sewage sludge	Electroplating, batteries, pigments, pesticides, stabilizer in plastics, tires	Headache, vomiting, chest pains, hypertension, emphysema, heart disease, suspected carcinogen and mutagen, kidney and liver disease	Toxic to fish in low concentrations
Lead	Mining, leaching	Batteries, gas additives, paint, tank linings, pipings	Anemia, kidney damage, CNS damage	Poisoning in domestic animals, birds, and fish
Mercury	Mining, leaching, volcanic action	Chlorine production (Chlor-alkali), scientific and industrial instruments, pesticides, batteries, contraceptive jellies and creams	Irritability, nervousness, depression, hallucinations, kidney damage, liver damage, CNS damage, fetus abnormalities	Reproductive failure, death of fish
Radiation				
Natural				
Cosmic	Solar system		Genetic mutation, cancer	Natural rate of genetic mutation, and cancer
Terrestrial	Soils, rocks, building materials			
Uranium-238				
Thorium-232				
Potassium-40				
Radon-222	Mining	Mined products, uranium fuel cycle	Lung cancer	
Manmade				
Medical				
X-ray		Dental and medical examinations, cancer treatment, medical treatment	Cancer, genetic mutation	
Cobalt-60				
Iodine-131	Pharmaceuticals			
Fallout	Weapons use, testing		Cancer, genetic mutation	Cancer, genetic mutation
Cesium-137				
Strontium-90				
Iodine-129				
Thorium				
Nuclear reactor	Controlled nuclear reaction	Electric power generation	Cancer, genetic mutation	Cancer, genetic mutation
Krypton-85				
Tritium				
Iodine-131				
Consumer products	Decay products of radionuclides	Watch dials, clock dials	Cancer, genetic mutation	Cancer, genetic mutation
Radium-226				

Sources:

Mineral facts and problems, U.S. Bureau of Mines (Washington: USGPO, 1976), bull. 667.

Summary characteristics of selected chemicals of near-term interest, EPA (Washington: USGPO, 1976), EPA 560/4-76-004.

Pest control: An assessment of present and alternative technologies, National Academy of Sciences (Washington, D.C., 1975), v. 1.

☐ Federal regulations on toxic substances were published in *Regulatory Reporter,* Interagency Regulatory Liaison Group (Washington: USGPO, 1978) v. 1, n. 1.

157

158

Pesticides

Pesticides are chemical compounds used to control plants and animals that are classified as pests. They are most widely used on crops, but they are also used in and around the home on insects, rodents, weeds, and plant diseases; in wood processing and preserving; in paint; in food storage; and in public health programs. Insect and weed control are the two most common uses.

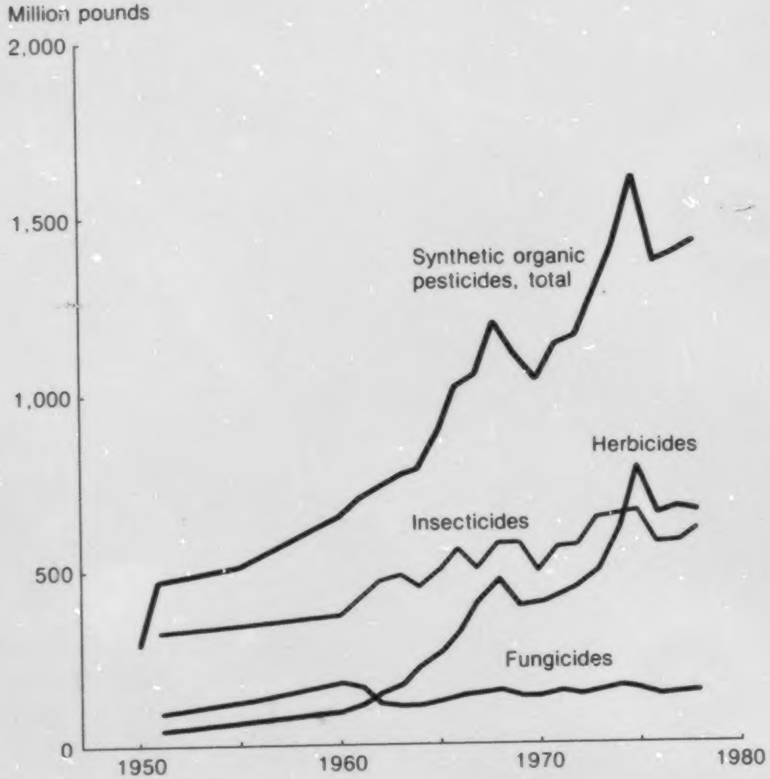
Some pesticides are applied directly to plants or soil. Soon after application, they are dispersed into the environment, so that applications are often repeated. As the pesticides accumulate in the soil and wash into streams and rivers, they can affect fish, birds, and other wildlife.

Pesticides reach humans through the food chain or by direct contact. Almost all people in the United States have measurable amounts of pesticides in their bodies.

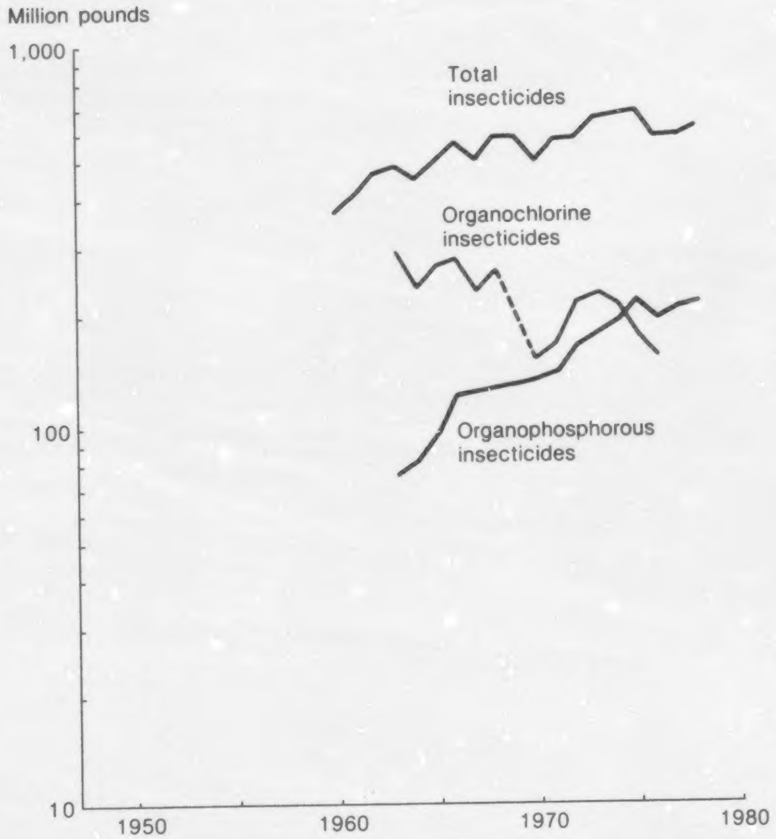
Because of the toxicity of pesticides in concentrated form and because of the frequency of exposure, the most serious human health effects are found among agricultural and production workers. Long-term and chronic health effects occur as the chemicals are ingested and inhaled. Bioaccumulation—the buildup of toxic materials in tissues—is evident in fish and birds as well as in humans.

Two-thirds of the insecticides used in agriculture are applied by aircraft, but only 25% to 50% of it reaches the crop. A large portion remains airborne and drifts or is lost through volatilization, leaching, and surface transport. Less than 1% actually comes in contact with an insect. Herbicides are usually applied directly to plants or the soil.

6-2
Synthetic organic pesticide production, by type, 1950-1978



6-3
Insecticide production, by type of chemical, 1960-1978



The use of synthetic organic chemicals to control pests grew rapidly after World War II. From 1950 to 1975, production increased at an average annual rate of 18%. With the worldwide grain shortage in 1973-1974, U.S. farmers brought millions of acres of food and feed grains into production and applied more pesticides than ever before. When agricultural expansion slowed, so did the production of pesticides.

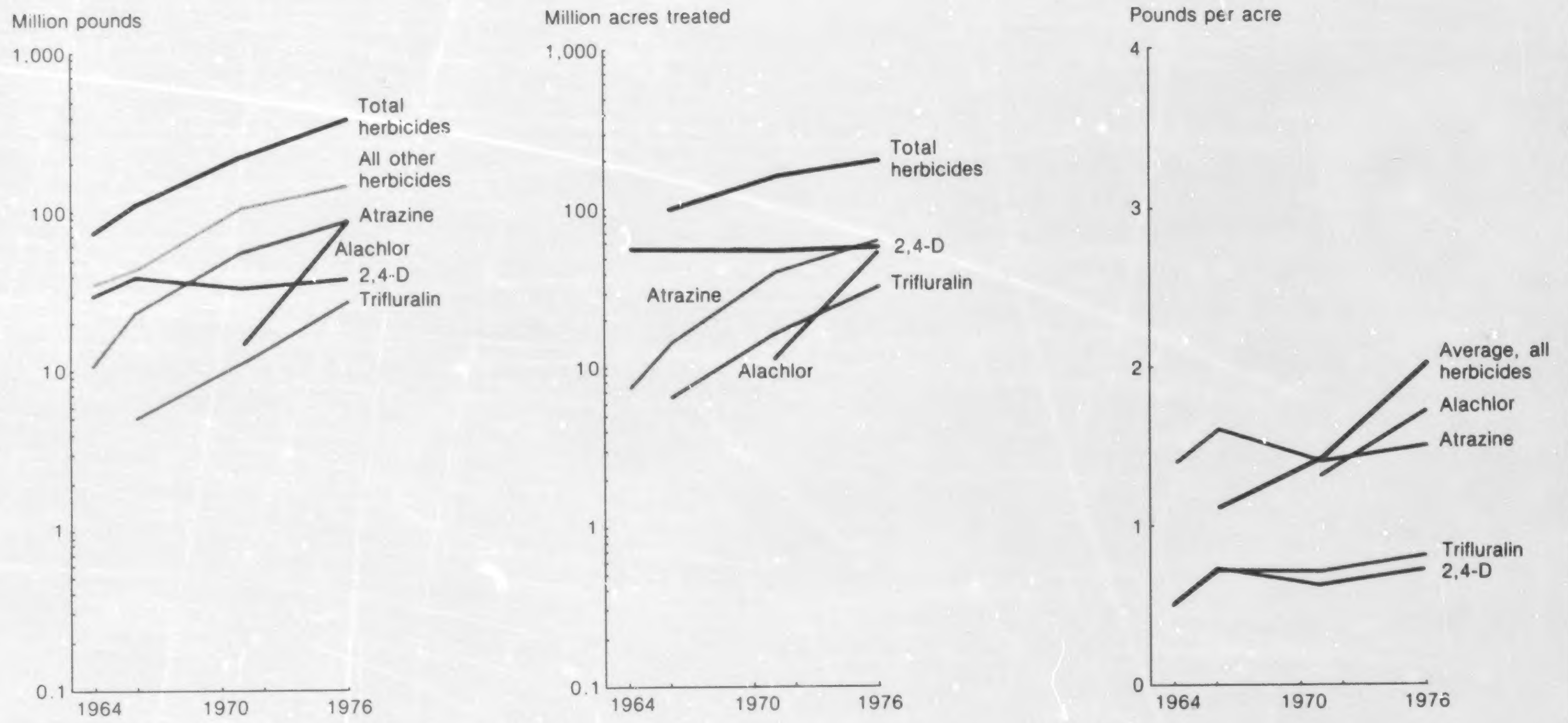
Since the early 1970s, there have been changes in the type of pesticides used. Farmers are increasing their use of herbicides as they move to the minimum-till method of plowing and preparing the soil for planting.

The total amount of insecticides applied to major crops has not increased appreciably in recent years, although use, measured in terms of acres treated, grew 32% from 1971 to 1976, largely because of increased corn applications.

Three major types of insecticides are used by farmers: organochlorines, organophosphates, and carbamates.

The organochlorine compounds are being replaced as it becomes evident that they cause extensive, possibly irreparable, harm to wildlife. Production of specific insecticides was restricted and use curtailed. DDT was banned for most uses by EPA in 1972, but some is still exported to tropical countries for mosquito control. Aldrin and dieldrin were banned for most uses in 1974. Heptachlor and chlordane were banned for crop use in 1975. Toxaphene, now the most widely used organochlorine, is under review, and its use may be limited.

6-4
Selected herbicides used by farmers on crops, 1964-1976

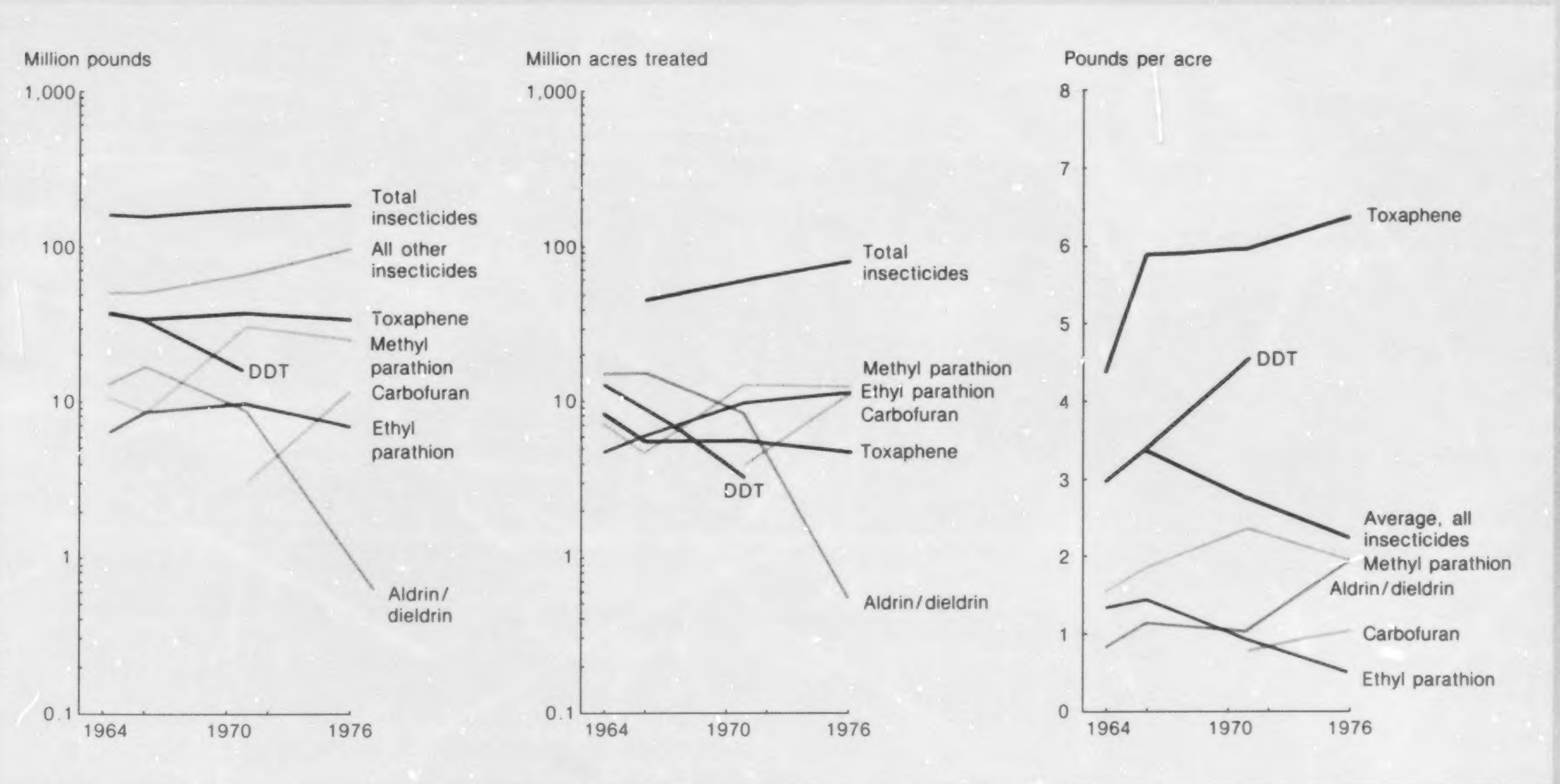


More herbicides than insecticides are now used in agriculture. Herbicides were applied to more than half of all cropland in 1976, whereas insecticides were applied to less than a fifth. This increase is the result of more frequent applications, treatment of more acreage, and the development of new kinds and combinations of herbicides.

The changes in use are dramatic. Between 1952 and 1976, corn acreage treated with herbicides increased from 11% to 90%. Cotton acreage increased from 5% to 84%.

Atrazine and alachlor, used mainly on corn, are the most common. Another herbicide, 2,4-D, is used on a wide variety of crops, including wheat, and on pastureland. Trifluralin is used widely on cotton and soybeans.

6-5
Selected insecticides used by farmers on crops, 1964-1976



The organophosphorous insecticides—methyl parathion, ethyl parathion, malathion, diazinon, fonofos, acephate, and phorate—are very toxic to both wildlife and humans when first applied, but they are less persistent than the organochlorines.

As recently as 1966, organochlorines accounted for 60% of all farm crop insecticides used. By 1976, the figure had dropped to 29%, and use of methyl parathion, ethyl parathion, malathion and other organophosphorous insecticides was at 49%. This change has helped reduce the residue problems because organophosphates break down more rapidly than the organochlorines. But when first applied, the organophosphates and carbamates are more acutely toxic to both wildlife and humans than the organochlorines.

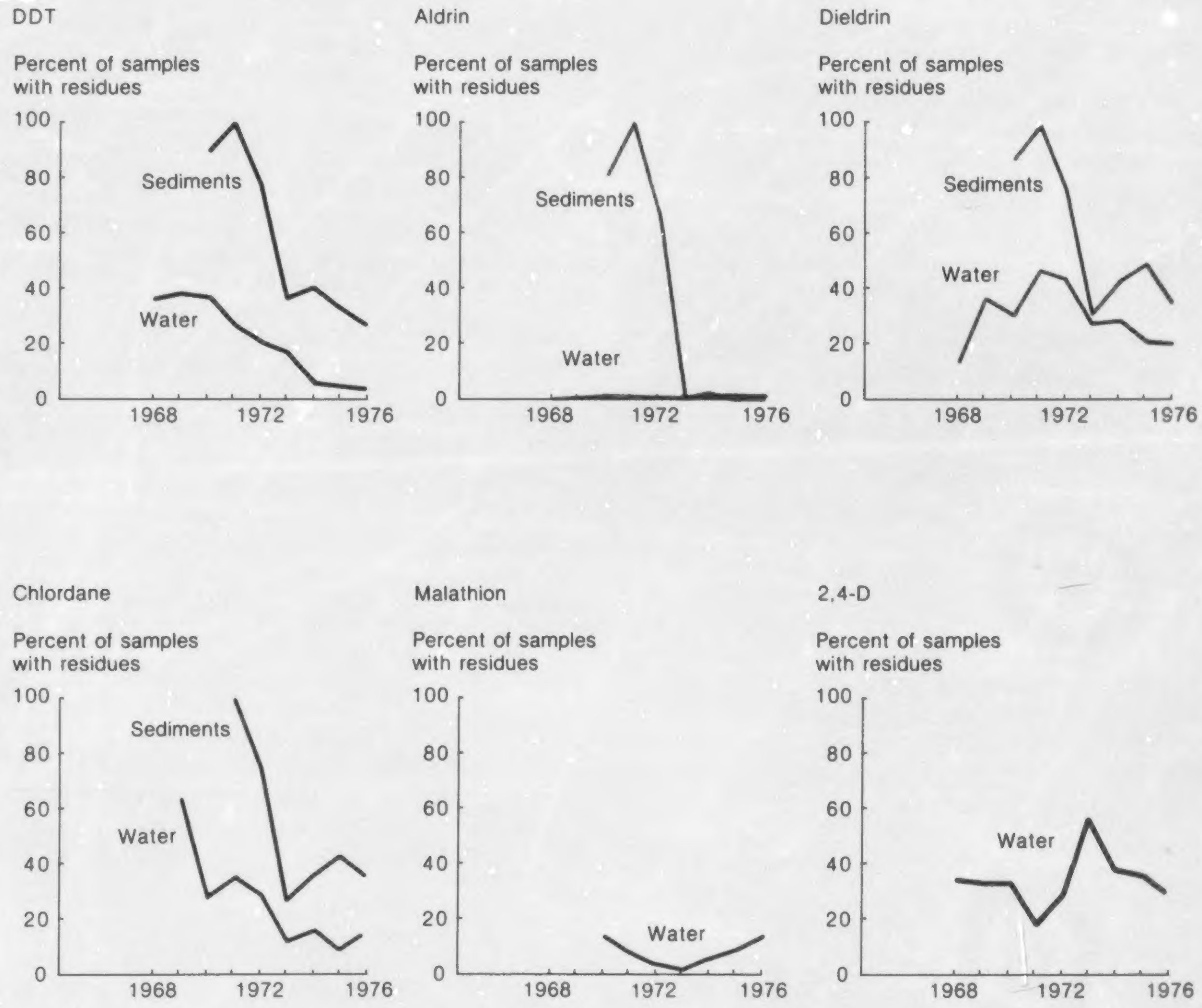
Among the insecticides, toxaphene, used extensively in the Mississippi Delta States on cotton crops, was used the most. It was followed by methyl parathion, also used on cotton, and carbofuran, used on corn.

6-6

Pesticide residues in river water and sediments in Texas, Louisiana, and Oklahoma, 1968-1976

Pesticide residues are found in streams, rivers, lakes, and coastal waters. They enter the waterways from agricultural runoff, urban runoff, accidental spills, and discharges at production sites. In 1976, 18 States listed pesticides as major pollutants of streams and rivers.

Pesticide residues in Oklahoma, Texas, and Louisiana rivers indicate the persistence of pesticides, particularly the organochlorines. Significant amounts of pesticides are still detected well after use was first restricted in 1972. Pesticide levels in sediment continue to be higher than in the water.



DDT

Aldrin

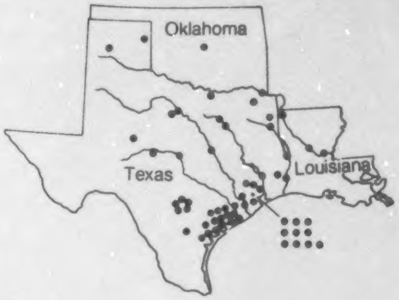
Dieldrin

Chlordane

Malathion

2,4-D

Stream monitoring sites



167

168

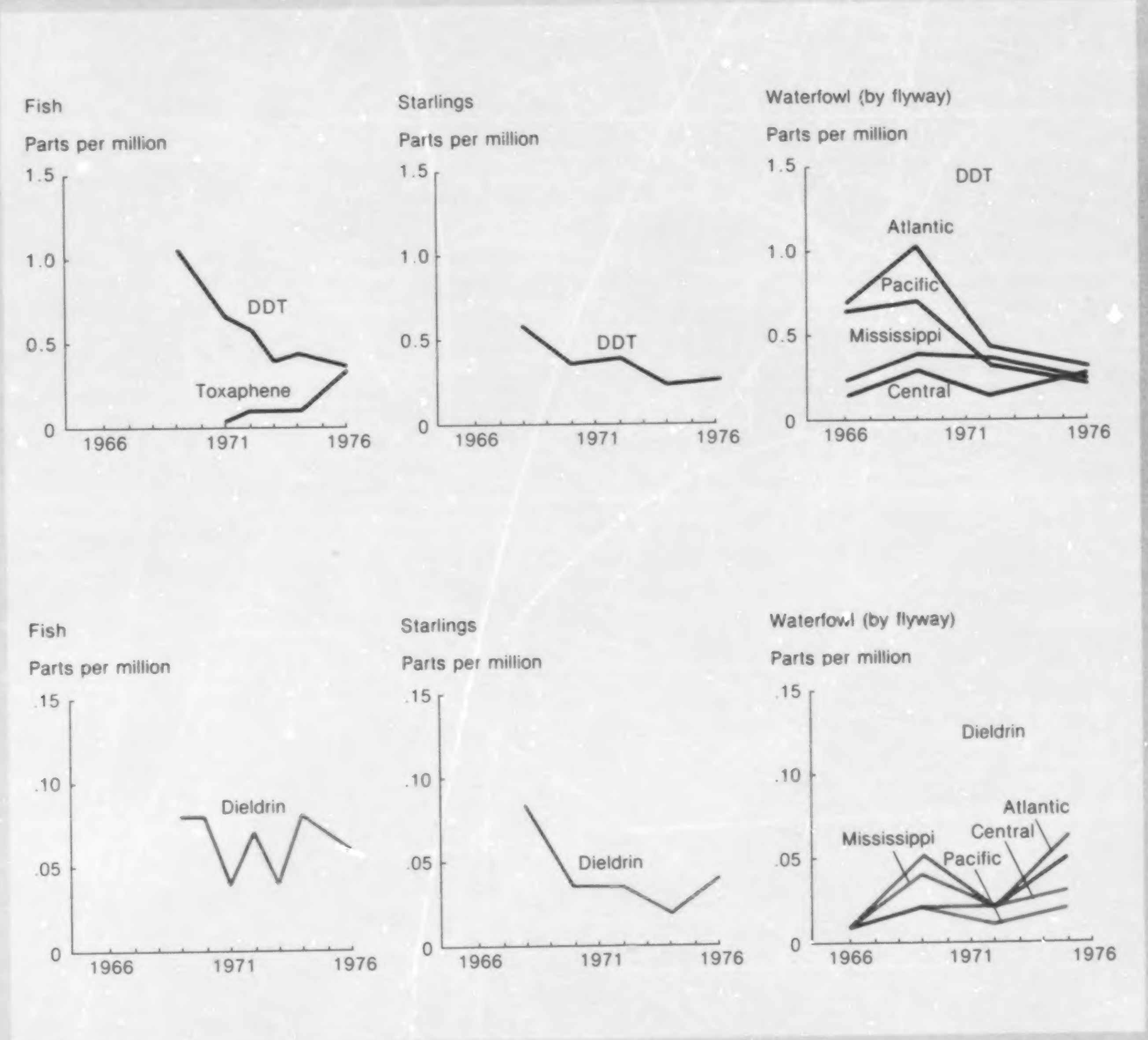
6-7
Pesticide residues in fish and birds, 1966–1976

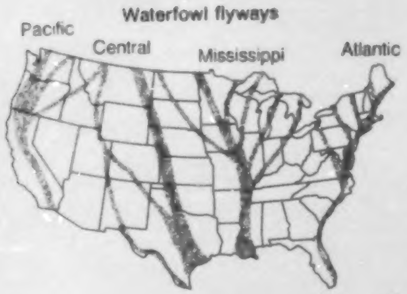
Fish and birds are good indicators of pesticide contamination because they feed on smaller animals and on crops, and they are found in almost every locale.

Residues of DDT, which was banned in 1972, have decreased in fish in the eight years of monitoring. Levels of toxaphene, used primarily in the South and Southeast, have increased.

DDT and dieldrin residue levels in starlings have not declined appreciably since 1970, although dieldrin was banned for most uses in 1974. The presence of DDT may be explained by its persistence in the environment, perhaps augmented by illegal use or importation.

Waterfowl in the Atlantic flyway have higher concentrations than those in less industrial regions.





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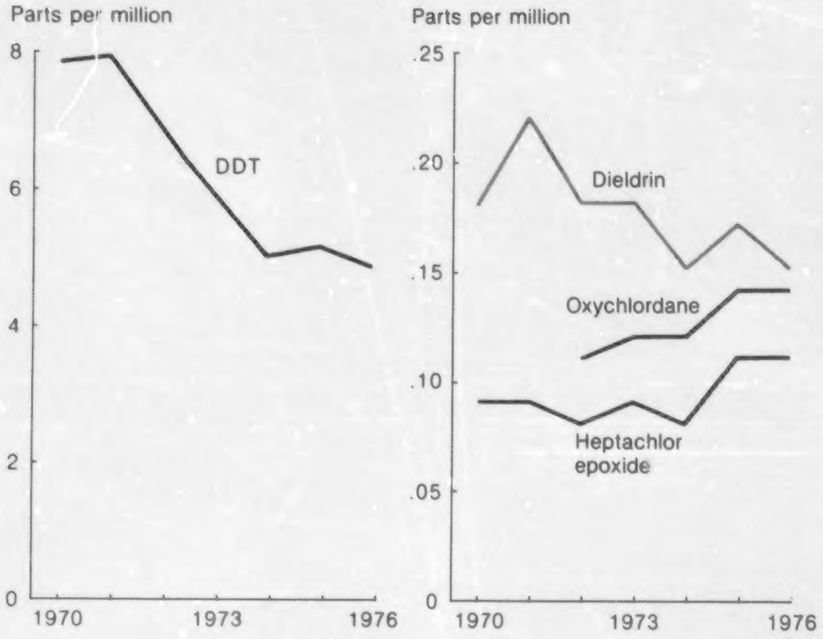
:31 170

6-8

Pesticide residues in human tissue, 1970-1976



Pesticides enter the human body through ingestion, through inhalation of aerosols and dusts, and through the skin. For organochlorine pesticides, residues of the parent compound or their metabolites are accumulated and stored in fatty tissue. These residues indicate the wide distribution of a pesticide and can signal a potential health hazard.

Organochlorine pesticides are in the fatty tissues of virtually everyone in the United States. The levels are not acutely hazardous, although many individual poisonings, other acute illness, and chronic illness have been treated.

DDT was detected in almost every human tissue sample analyzed. There has been a reduction in concentration since the early 1970s, but the frequency remains the same.

Low levels of dieldrin were found in almost all tissues analyzed. Concentrations remained appreciably unchanged during the survey years.

Oxychlordane and heptachlor epoxide, representative of the pesticides chlordane and heptachlor, were also found at low levels but with high frequency.

Sources and technical notes

6-2
Synthetic organic pesticide production, by type, 1950-1978

Synthetic organic chemicals 1978, International Trade Commission (Washington: USGPO, 1979), and previous annual issues.

The International Trade Commission publishes production and sales data for a synthetic organic chemical only if three or more companies produce it. Because most pesticides are patented and are produced by fewer than three companies, production data do not become public knowledge. Production data include the quantity made available by the original manufacturers only; they exclude intermediate products. About a fourth of the amount produced is exported.

National pesticide use is currently monitored for agriculture only; missing from the totals is the approximately 40% used in or around the home, in government, and in the commercial sector.

Data from quinquennial USDA farm surveys (see sources in 6-4) are made public approximately 2 years after the data are collected.

Insecticides include fumigants, rodenticides, and a small quantity of synthetic soil conditioners.

6-3
Insecticide production, by type of chemical, 1960-1978

Synthetic organic chemicals 1978, International Trade Commission (Washington: USGPO, 1979), and previous annual issues; organochlorine data for 1970-1976 were estimated from a graph in the 1976 issue (USGPO, 1977), p. 268.

Insecticides include rodenticides, soil conditioners, and fumigants. Organophosphorous data are not available for 1967-1969. Because of confidentiality rules, carbamate data are not available.

6-4
Selected herbicides used by farmers on crops, 1964-1976

1964: *Quantities of pesticides used by farmers in 1964*, USDA Economic Research Service (Washington: USGPO, 1968), agr. econ. rep. 131, pp. 19, 20.

1966: *Quantities of pesticides used by farmers in 1966*, USDA Economic Research Service (Washington: USGPO, 1970), agr. econ. rep. 179, tables 23, 25, pp. 37, 38, 44.

1971: *Farmers' use of pesticides in 1971—Quantities*, USDA Economic Research Service (Washington: USGPO, 1974), agr. econ. rep. 252, pp. 9, 40, 41.

1976: *Farmers' use of pesticides in 1976*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1978), agr. econ. rep. 418, pp. 9, 36, 38.

6-5
Selected insecticides used by farmers on crops, 1964-1976

1964: *Quantities of pesticides used by farmers in 1964*, USDA Economic Research Service (Washington: USGPO, 1968), agr. econ. rep. 131, pp. 26, 27.

1966: *Quantities of pesticides used by farmers in 1966*, USDA Economic Research Service (Washington: USGPO, 1970), agr. econ. rep. 179, tables 28, 30, pp. 50-55. *Extent of farm pesticide use on crops in 1966*, USDA Economic Research Service (Washington: USGPO, 1968), agr. econ. rep. 147, p. 9.

1971: *Farmers' use of pesticides in 1971—Quantities*, USDA Economic Research Service (Washington: USGPO, 1974), agr. econ. rep. 252, pp. 13, 50.

1976: *Farmers' use of pesticides in 1976*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1979), agr. econ. rep. 418, pp. 15, 48, 52.

DDT includes its related compound TDE.

Aldrin/dieldrin data for 1976 include aldrin only. Because aldrin rapidly breaks down into its metabolite, dieldrin, most residues are dieldrin.

6-6
Pesticide residues in river water and sediments in Texas, Louisiana, and Oklahoma, 1968-1976

Environmental quality—1977, Council on Environmental Quality (Washington: USGPO, 1977), p. 242, UPGRADE analysis of U.S. Geological Survey data collected at 60 stream monitoring sites.

Data are annual composite detection rates. Other agricultural regions may have concentrations as high as or higher than these. These levels are functions of monitoring and do not reflect the extent of the problem elsewhere.

6-7
Pesticide residues in fish and birds, 1966-1976

Fish: U.S. Fish and Wildlife Service, Columbia National Fisheries Research Laboratory, Columbia, Mo., unpublished data.

Starlings, 1968: "Nationwide residues of organochlorines in starlings, 1974," Donald H. White, *Pesticides Monitoring J.* 10:15 (1976). 1970-1976: "Nationwide residues of organochlorines in starlings, 1976," Donald H. White, *Pesticides Monitoring J.* 12:197 (1979).

Waterfowl, 1966: Based on "Occurrences of PCB in National Fish and Wildlife Monitoring Program," Charles R. Walker, U.S. Fish and Wildlife Service. 1969: "Nationwide residues of organochlorines in wings of adult mallards and black ducks, 1972-1973," Donald H. White and Robert G. Heath, *Pesticides Monitoring J.* 9:184 (1976). 1972-1976: "Nationwide residues of organochlorines in wings of adult mallards and black ducks, 1976," Donald H. White, *Pesticides Monitoring J.* 13:16 (1979).

Freshwater fish were sampled in 50 States as part of the National Pesticide Monitoring Program. Two-thirds of the fish were carp, suckers, catfish, and other bottom-dwelling species. The remaining were predacious species: trout, walleye, bass, and bluegill. The whole fish was analyzed. Data are in terms of geometric mean. DDT includes its derivatives. Dieldrin includes aldrin.

Starlings were sampled in the coterminous 48 States as part of the National Pesticide Monitoring Program. Feet, beaks, wingtips, and skins were removed and the remainder analyzed. Approximately 1,400 starlings were analyzed each year. Data are in terms of geometric mean, wet weight. DDT refers to its derivative, DDE.

Waterfowl residues were sampled in the 48 States as part of the National Pesticide Monitoring Program. Each year more than 5,000 samples were drawn from adult mallard wings sent to the U.S. Fish and Wildlife Service by sportsmen. Data are in terms of mean wet weight. DDT data for 1966 refer only to its derivative, DDE; for 1969-1976, data include its metabolites.

6-8
Pesticide residues in human tissue, 1970-1976

1970-1974: "Survey of pesticide residues and their metabolites in humans," R. W. Kutz, S. C. Strassman, and A. R. Yobs, *Pesticide management and insecticide resistance* (New York: Academic Press, Inc., 1977), tables 4-7, pp. 530-534.

1975-1976: Environmental Protection Agency, Office of Toxic Substances, unpublished data.

Data are for fiscal years.

Pesticide residues and associated chemicals were measured in the 48 coterminous States as part of the National Human Monitoring Program for Pesticides.

Approximately 2,000 samples were collected each year by medical pathologists from selected cities. Individuals with known or suspected pesticide poisoning were excluded.

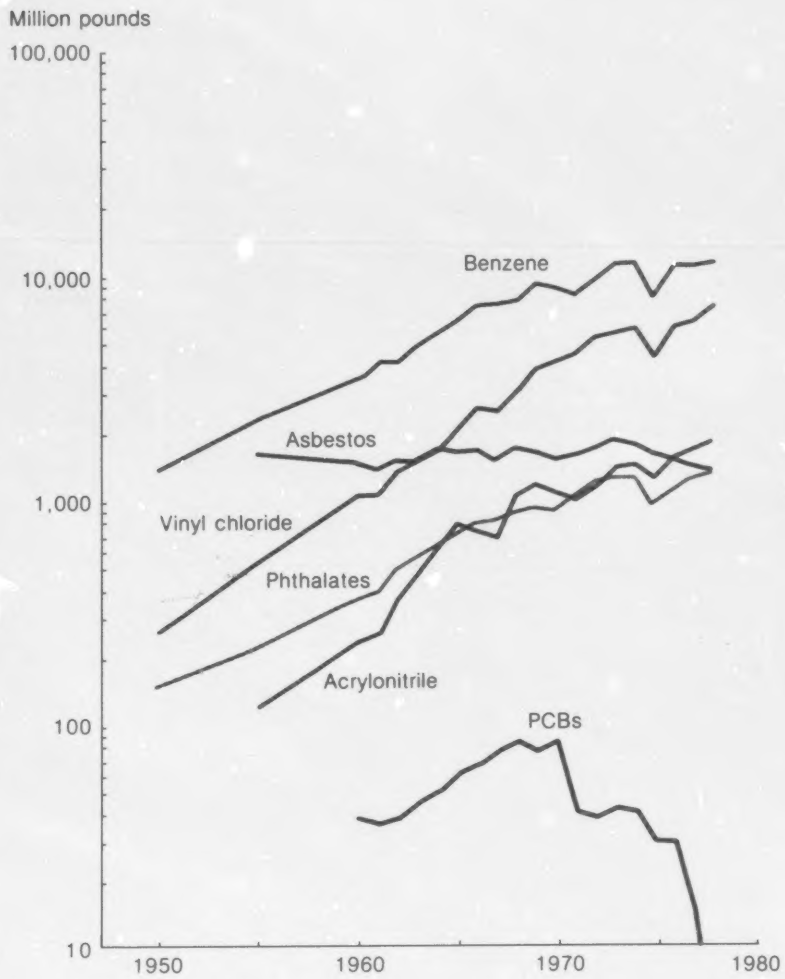
Data are in terms of geometric mean, lipid basis. DDT includes its metabolites.

Industrial chemicals

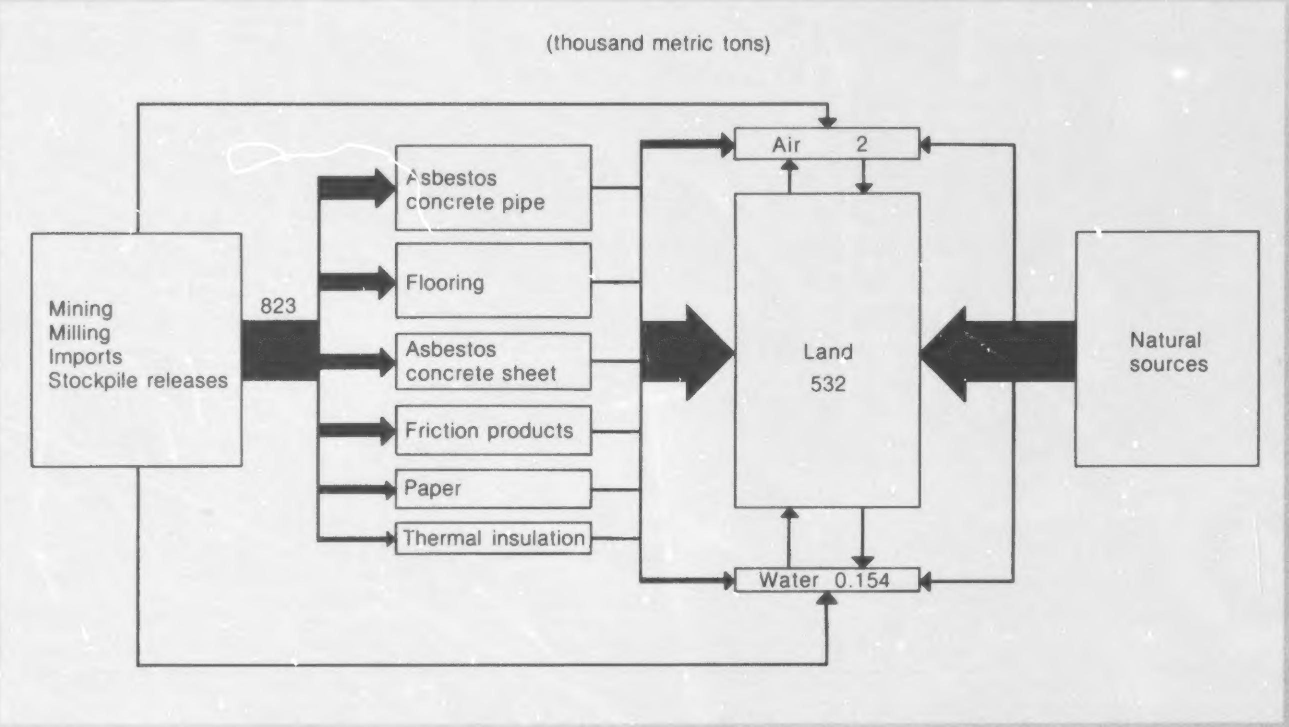
Many chemicals found in industrial, commercial, and household environments are toxic under certain conditions. Among the most common are asbestos, benzene, vinyl chloride, acrylonitrile, and phthalates. All are important industrial materials widely distributed in various forms, and all have serious health effects. Polychlorinated biphenyls (PCBs) were important industrial chemicals until their effects were demonstrated and production was stopped.

Asbestos, a class of minerals, is used in more than 2,000 products and processes, including piping, construction, fireproofing, and brake linings. Benzene, an organic compound derived from petroleum, is an intermediate in the production of plastics, dyes, nylon, food additives, detergents, drugs, and fungicides. It is also used as a gasoline additive. Phthalates, a class of intermediate synthetic organic chemicals, are in widespread and growing use as a resin in the production of plastics, model cement, paints, and finishes. Acrylonitrile is used as a resin in the production of plastic bottles, acrylic fibers, and textiles. Combined with butadiene and styrene, acrylonitrile forms a polymer, ABS, widely used in appliances, automobiles, luggage, telephones, and many other common industrial and household products. Vinyl chloride is a gas used in the production of plastics. PCBs, liquids previously used in ink solvents, adhesives, textile coatings, and pesticides, are now used only in electrical transformers and other closed systems, but many products containing PCBs remain in use.

6-9
Production of selected industrial chemicals, 1950-1978



6-10
Flow of asbestos in the environment



Production of benzene, phthalates, acrylonitrile, and vinyl chloride has increased rapidly during the past 20 years. Almost 11 billion pounds of benzene were produced in 1978, making it one of the high-volume organic compounds in domestic production.

Vinyl chloride production continues to grow, along with the use of plastics in industrial and consumer products.

Asbestos production, on the other hand, has not increased appreciably. In fact, it has declined, with imports from Canada taking its place.

PCB production has declined since 1970 as a result of self-imposed restrictions by the major manufacturer. By law, the manufacture of PCBs was prohibited after July 1979, except when specifically exempted by EPA.

The flow of industrial chemicals into the environment varies with the chemical. Asbestos and benzene are present in varying concentrations throughout the environment including natural sources of asbestos.

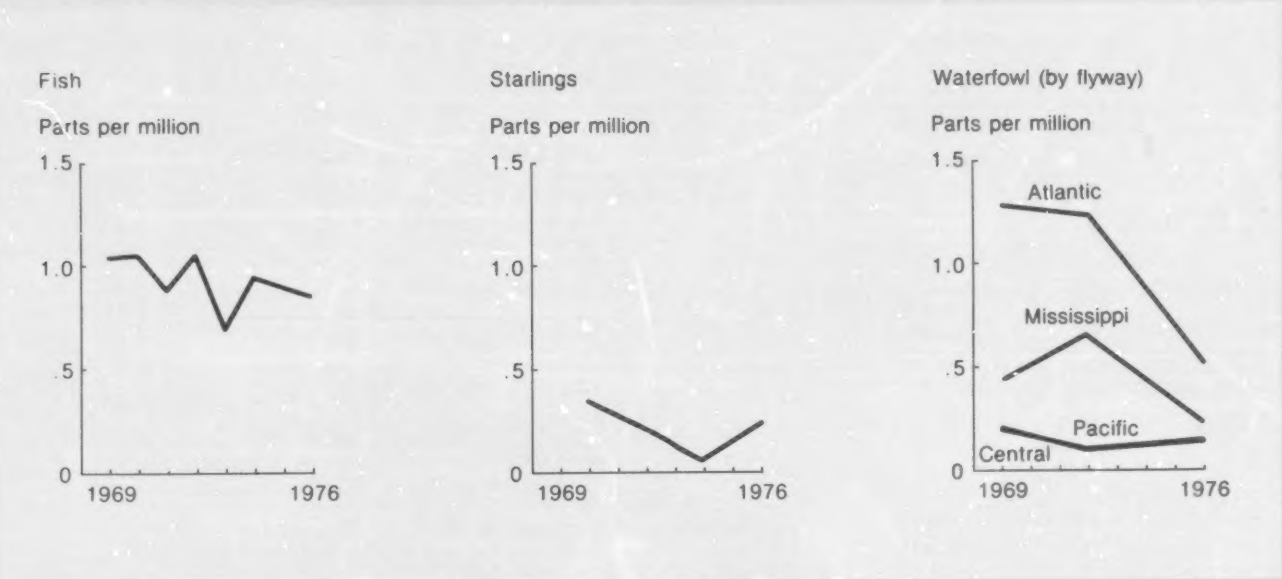
Most asbestos fibers that are released directly into the air come from mining and milling. These stages are no longer a major factor in asbestos contamination in the United States because nearly 90% is imported from Canada. Once an asbestos product has been manufactured, release of fibers into the environment is highest in the use of brake linings and other friction products and in the deterioration of thermal insulation and construction materials. Demolition of buildings is an important source of asbestos contamination. Asbestos is also leached into drinking water from concrete water pipes.

Health hazards are present from mining to disposal. Industrial workers and miners are usually the most affected. As materials made with asbestos deteriorate, the general public can be exposed.

Vinyl chloride gas is released directly at the workplace, although small amounts are released as consumer products deteriorate and are disposed of. Acrylonitrile and phthalates are synthetic compounds primarily released at the workplace.

The major source of PCBs is through improper waste disposal, especially into bodies of water. PCBs contaminate wildlife, fish in particular. The threat to human health is through the food chain—in fish, poultry, and meat. PCBs are widely distributed in the environment very much like DDT, which PCBs resemble structurally, and, like DDT, they are highly persistent.

6-11
PCB residues in fish and birds, 1969-1976



PCBs are the most frequently found synthetic material in fresh water food chains. Just as they persist in soil, air, and water, they remain in the tissue of animals that ingest them and become concentrated as they move up the food chain.

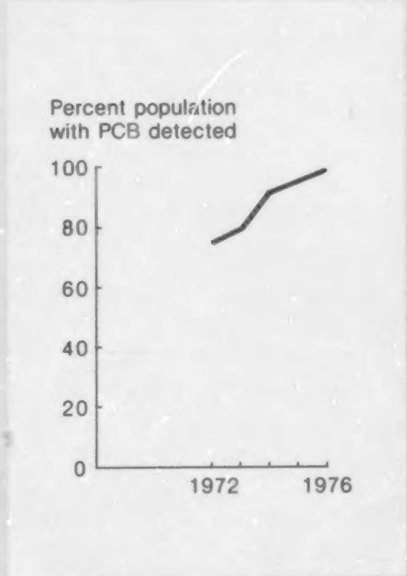
At high concentrations, PCBs are acutely toxic and can cause death to wildlife. Chronic effects of lower concentrations include eggshell thinning and lower reproductive capacity in birds and fish.

PCB contamination in fish appears to be declining, but some localities have very high levels.

PCB residues in starlings increased significantly from 1974 to 1976.

PCB levels in waterfowl have declined noticeably along the Atlantic and Mississippi flyways, both primary locations of chemical plants and disposal grounds.

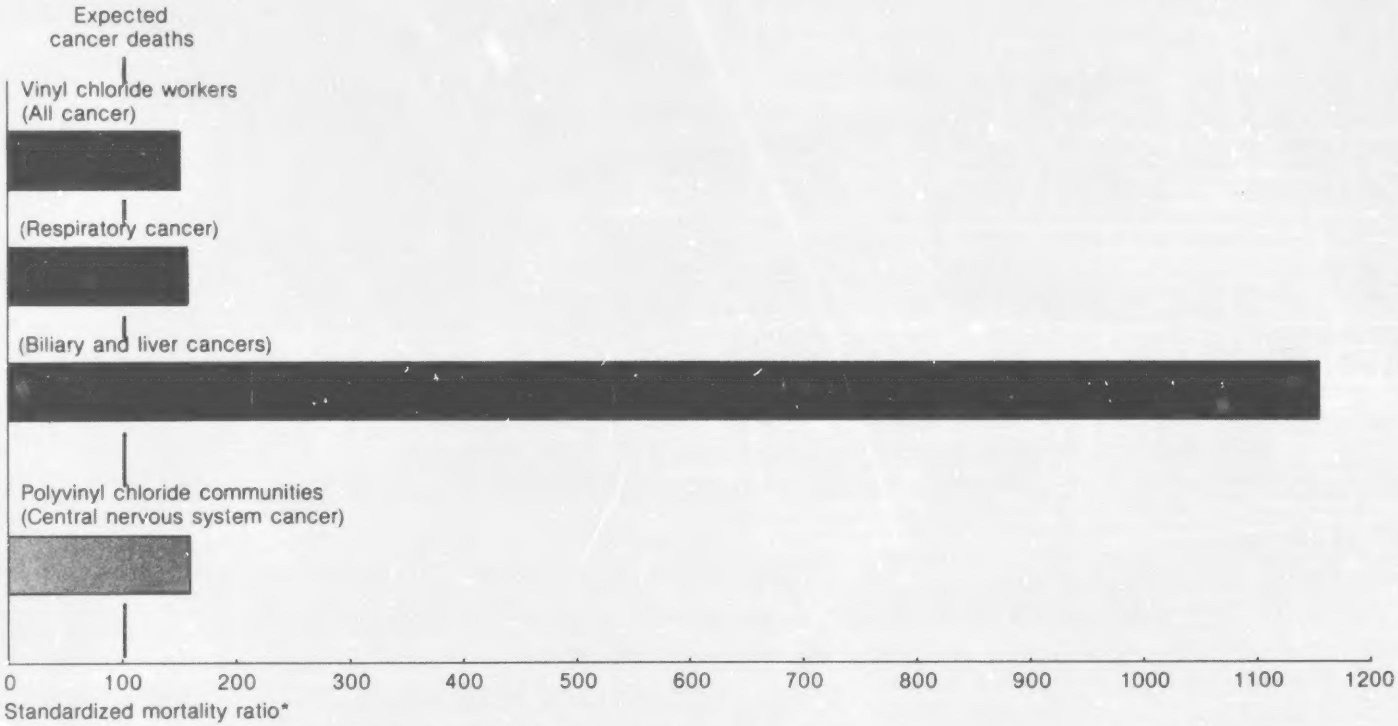
6-12
PCB residues in human tissue, 1972–1976



In humans, the percentage of the population with detected PCB residues in fatty tissue increased from 1972 to 1976. Contamination is most prevalent in the North Central and Atlantic States, but at present levels PCBs do not appear to present an imminent hazard.

In 1974, residents along Lake Michigan were advised not to eat more than one meal per week of fish caught in Lake Michigan in order to keep their PCB blood levels below Federal standards. Residents along the Hudson River from Troy to New York City were warned of PCB contamination in fish in 1976, and a fishing ban is in effect for 60% of the commercial species.

6-13
Cancer deaths associated with vinyl chloride and polyvinyl chloride, 1942–1973



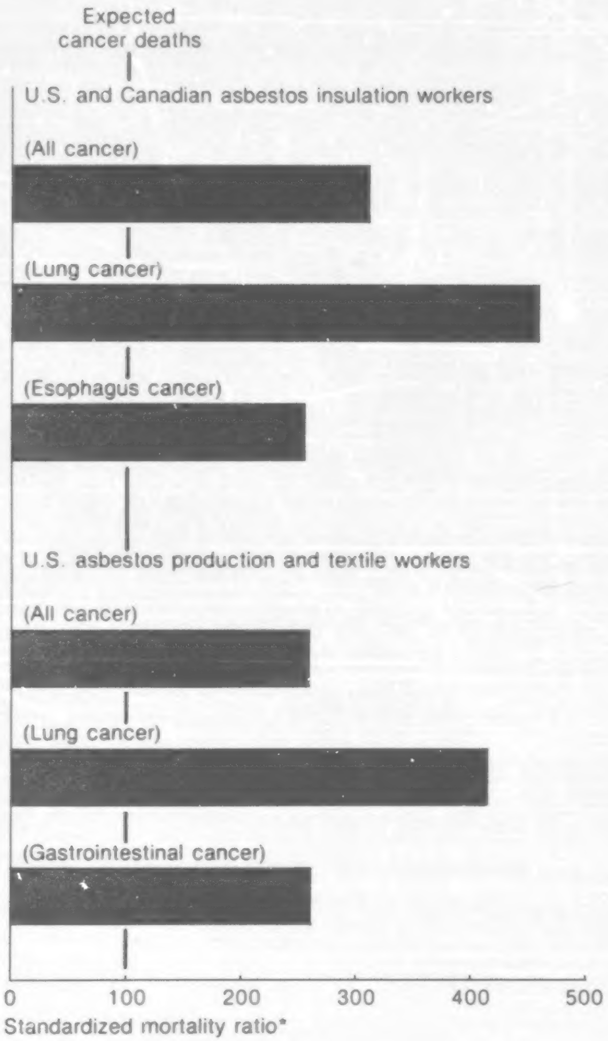
*The ratio of the number of observed to expected cancer deaths times 100.

Workers tend to suffer the most serious effects of exposure to toxic forms of these industrial chemicals. Cancer mortality for vinyl chloride workers is 50% higher than for the general population. Their rates for biliary and liver cancers, relatively rare diseases, are startlingly high. Residents of communities with polyvinyl chloride (PVC) plants also have higher cancer rates than the general population.

Vinyl chloride exposure does more than induce cancer. It produces birth anomalies at three times the expected rate and acute symptoms in the central nervous system, liver, lungs, and bones of the fingers.

6-14

Cancer deaths associated with asbestos, 1959–1977



*The ratio of the number of observed to expected cancer deaths times 100.

Prolonged exposure to high concentrations of asbestos dust increases the chances of asbestosis (an often fatal disease affecting the lungs), mesothelioma (a rare cancer of the chest and stomach lining), and cancer of the gastrointestinal tract and lung.

Asbestos insulation workers have mortality rates from cancer three times that of the general population. Their lung cancer rate is more than four and a half times higher. Asbestos production and textile workers also have a higher mortality from cancers.

Risk of asbestos contamination and cancer extends beyond the workers. Mesothelioma has been found among families of asbestos workers and among people living within a quarter-mile of production or fabricating plants.

Excessive exposure to benzene fumes can lead to abnormal blood cell formation in bone marrow, to anemia, and to death. Recent studies of benzene workers have shown that they are several times more likely than the general population to contract leukemia.

6-9
Production of selected industrial chemicals, 1950-1978

Benzene, vinyl chloride, acrylonitrile, phthalates: *Synthetic organic chemicals 1978*, International Trade Commission (Washington: USGPO, 1979), and previous annual issues.

Asbestos, 1955: *Mineral facts and problems*, U.S. Bureau of Mines (Washington: USGPO, 1976), p. 120. 1960-1978: *Asbestos*, U.S. Bureau of Mines (Washington: USGPO, 1979), mineral commodity profiles, p. 17.

PCBs, 1960-1971: *Polychlorinated biphenyls and the environment*, Interdepartmental Task Force on PCBs (Washington: USGPO, 1972), pp. 6, 7. 1972-1978: Monsanto Industrial Chemicals Company, unpublished data.

One gallon of benzene equals 7.31 pounds.

Data for asbestos are for primary demand; 1978 asbestos data are estimated.

PCB data include only that produced for domestic sale.

Data for benzene, phthalates, acrylonitrile, and vinyl chloride include only that produced by the original manufacturers; they exclude intermediate products.

6-10
Flow of asbestos in the environment

Based on *Asbestos: An information resource*, U.S. Department of Health, Education, and Welfare, National Institutes of Health (Washington, D.C., 1978), p. 53.

6-11
PCB residues in fish and birds, 1969-1976

See 6-7.

Data are for fiscal years.

6-12
PCB residues in human tissue, 1972-1976

1972: "Organochlorine pesticide residues in human adipose tissue," F. W. Kutz, A. R. Yobs, and S. C. Strassman, *Bull. Soc. Pharmacol. Environ. Pathol.* 4:19 (1976).

1973-1976: Environmental Protection Agency, Office of Toxic Substances, National Human Monitoring Program, unpublished data.

Data are for fiscal years.

See 6-8 for information on the National Human Monitoring Program.

6-13
Cancer deaths associated with vinyl chloride and polyvinyl chloride, 1942-1973

"Neoplastic risk among workers exposed to vinyl chloride," Richard J. Waxweiler, et al. "Oncogenic and mutagenic risks in communities with polyvinyl chloride production facilities," Peter R. Infante. *Annals of the New York Academy of Sciences: Occupational carcinogenesis* 271: 41, 43, 49, 52, 55 (1976).

Data are for 1,294 workers with at least 5 years' experience in a vinyl chloride or polyvinyl chloride plant and for whom at least 10 years had elapsed since their initial employment. The study was conducted in 1972. Of 136 deaths, 35 were attributed to cancers.

The polyvinyl chloride communities studied were Ashtabula, Painesville, Avon Lake, and North Ridgeville, all northern Ohio communities with a total of more than 66,000 residents in 1972. Observed and expected cancer deaths and standardized mortality ratios were developed for residents 45 years and older for the years 1958-1973, a period when 38 people died from a cancer of the central nervous system.

6-14
Cancer deaths associated with asbestos, 1959-1977

Insulation workers: "Asbestos-associated disease in U.S. shipyards," Irving J. Selikoff, Environmental Science Laboratory, Mt. Sinai School of Medicine, memorandum to the National Institute of Environmental Health Sciences, November 27, 1977, table 1.

Production and textile workers: "Case study 1: Asbestos—The TLV approach," William J. Nicholson, *Annals of the New York Academy of Sciences: Occupational carcinogenesis* 271:156 (1976).

From 1967 to 1977, 17,800 asbestos insulation workers were studied. Of 2,270 deaths, 994 were attributed to cancers.

From 1959 to 1977, 689 asbestos production and textile workers were studied. Of 199 deaths, 72 were attributed to cancers.

Gastrointestinal cancers include cancer of the stomach, colon, rectum, and esophagus.

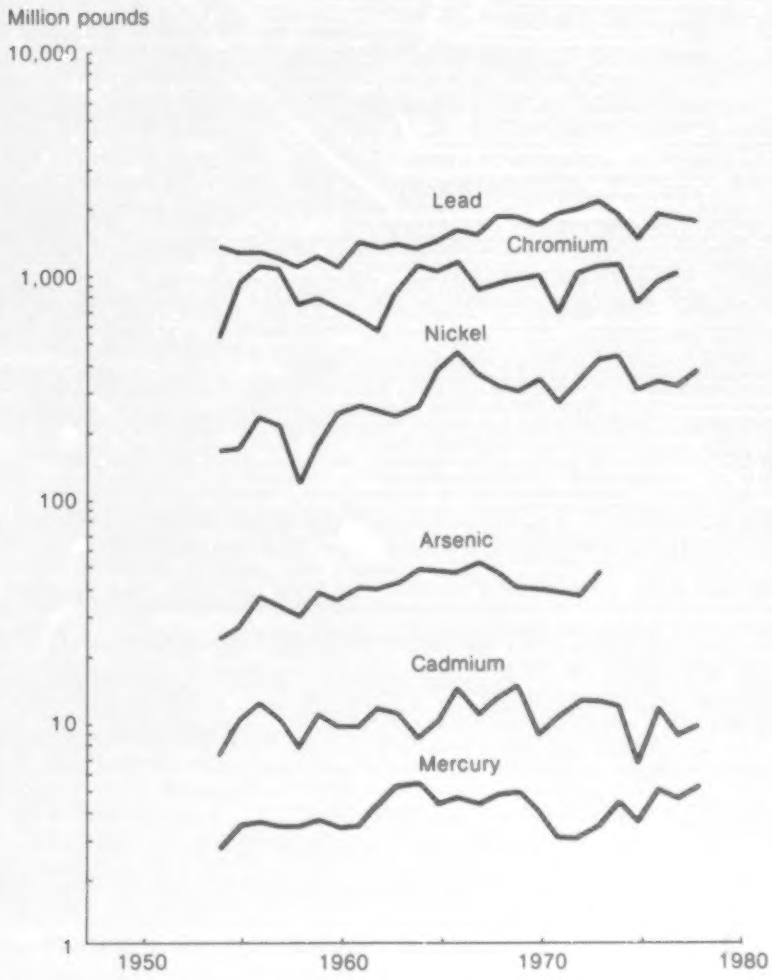
Lung cancers include cancer of the pleura, trachea, and bronchus.

Metals

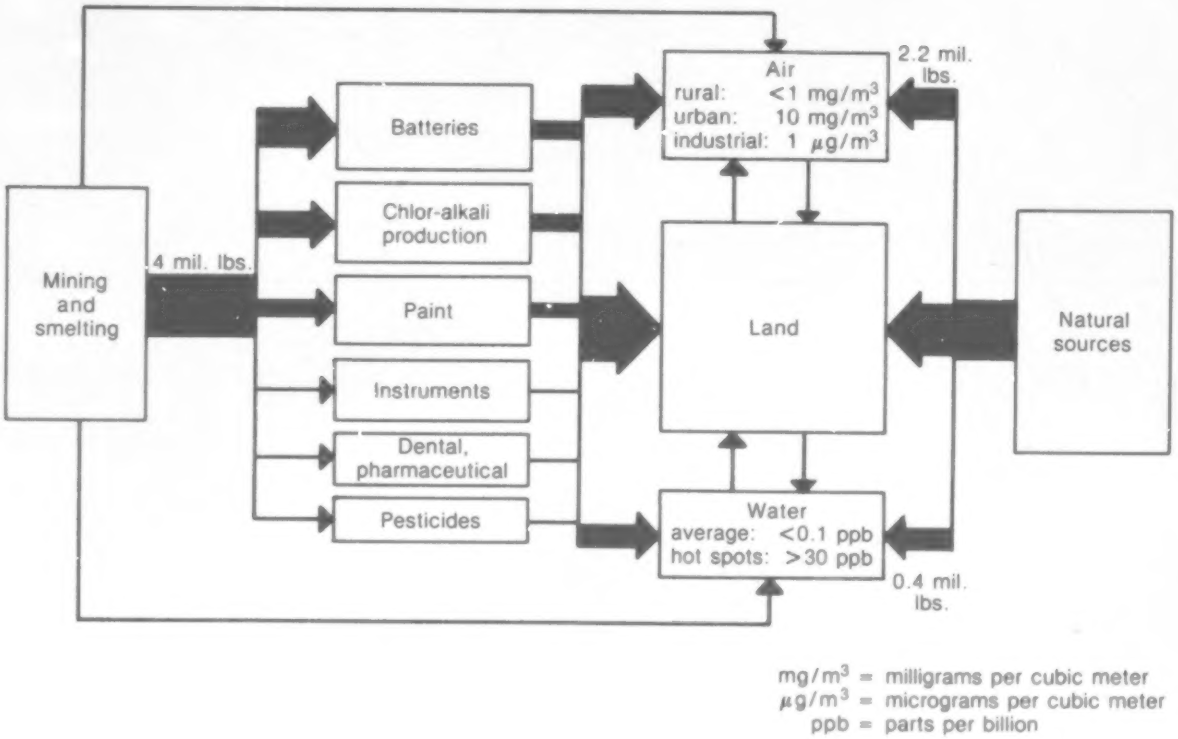
Metals are elements that occur naturally. Many are widespread in the environment as a result of industrial and agricultural processes. Trace quantities of many metals are essential nutrients for humans, plants, and other animals. At higher concentrations and in specific forms, some metals interfere with vital chemical reactions in living organisms, influencing reproduction and causing disease. Among the most common toxic metals are various forms of lead, mercury, chromium, nickel, cadmium, and arsenic.

Intractable problems with these metals relate to their disposal. Wastes containing metals are often discharged directly in rivers and streams or are dumped in landfills from which they leach into ground and surface waters. Many toxic metallic compounds are persistent, and they accumulate in wildlife and human tissues.

6-15
Primary demand for selected metals, 1954–1978



6-16
Flow of mercury in the environment



Mining and smelting
4 mil. lbs.
Batteries
Chlor-alkali production
Paint
Instruments
Dental, pharmaceutical
Pesticides
Air
rural: <1 mg/m^3
urban: 10 mg/m^3
industrial: 1 μg/m^3
2.2 mil. lbs.
Land
Natural sources
Water
average: <0.1 ppb
hot spots: >30 ppb
0.4 mil. lbs.
mg/m^3 = milligrams per cubic meter
μg/m^3 = micrograms per cubic meter
ppb = parts per billion

The primary demand for metals—the amount of new materials entering use—has risen steadily for more than 20 years. (Year-to-year changes have generally been caused by short-term economic fluctuations.) But primary demand is only the beginning, and the total amount in the ambient environment may be many times greater. For example, an average of 4 million pounds of mercury is brought into commercial use each year. Since 1954, then, 100 million pounds of mercury have been mined, used, and reused or disposed of. This figure does not include the large amount released from processes other than those involved in production of the metal, for example, from coal combustion.

Throughout the environment, metals are present in varying concentrations, and their pathways vary as well.

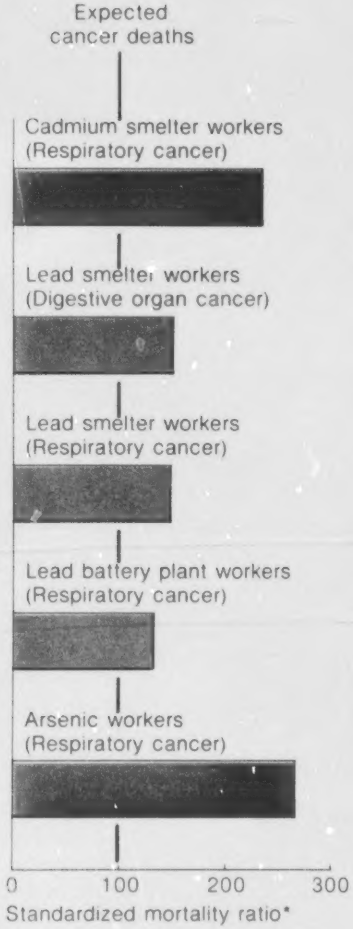
Mercury, the only common liquid metal, is released directly into the air during mining and smelting, from weathering of paint, and from losses during industrial processing. It leaches into water from old batteries and other discarded products and into soils directly from industrial uses, pesticides, and waste disposal. Proportionally, soils receive the most mercury, and erosion carries a significant amount to waterways.

In water, bacterial action can change mercury into methylmercury, which is easily ingested by fish of all types and is accumulated in their fatty tissue. Since the late 1950s, nearly 300 Japanese have died and many more have been seriously affected by Minamata disease, caused by eating fish polluted with methylmercury. In the United States, parts of two rivers, the North Fork of the Holston and the Shenandoah in Virginia, remain closed to fishing because of mercury contamination.

Mercury evaporates and it leaches into water from natural ore bodies at rates that are sometimes higher than those from human activity. Industrial discharges, however, are generally more concentrated and are released in populated areas.

6-17

Cancer deaths associated with metals, 1940-1973



*The ratio of the number of observed to expected cancer deaths times 100.

Some forms of cancer are linked directly to metals contamination. Most at risk are the people who work in particular industries or live near plants where production safeguards are inadequate.

Arsenic workers have respiratory cancer mortality almost three times the expected rate. That for cadmium smelter workers is more than twice the expected rate, and lead smelter workers' is a third higher than expected. (The excess cancer rate in lead smelter workers may be attributable to the arsenic in the ore rather than to the lead.) Lead has been linked to cancers of the respiratory and digestive organs, arsenic to cancer of the skin, mouth, and nose.

Other serious and chronic health effects can result from metal poisoning and contamination. Lead and mercury are historically associated with mental disability, lead and arsenic with digestive difficulties, cadmium with kidney disease, and lead with anemia.

6-15
Primary demand for selected metals, 1954–1978

Lead, 1954–1976: *Lead*, U.S. Bureau of Mines (Washington, D.C., 1977), mineral commodity profiles, p. 21. 1977–1978: U.S. Bureau of Mines, unpublished data.

Chromium, 1954–1976: *Chromium*, U.S. Bureau of Mines (Washington, D.C., 1977), mineral commodity profiles, p. 14. 1977: U.S. Bureau of Mines, unpublished data.

Nickel, 1954–1978: *Nickel*, U.S. Bureau of Mines (Washington, D.C., 1979), mineral commodity profiles, p. 18.

Arsenic, 1954–1973: *Mineral facts and problems, 1975*, U.S. Bureau of Mines (Washington: USGPO, 1976), p. 105.

Cadmium, 1954–1957: *Mineral facts and problems, 1975*, U.S. Bureau of Mines (Washington, USGPO, 1976), p. 203. 1958–1978: *Cadmium*, U.S. Bureau of Mines (Washington, D.C., 1979), mineral commodity profiles, pp. 11, 203.

Mercury, 1954–1973: *Mineral facts and problems, 1975*, U.S. Bureau of Mines (Washington: USGPO, 1976), p. 681. 1974–1978: *Mineral commodity summaries 1979*, U.S. Bureau of Mines (Washington: USGPO, 1979), p. 96.

Chromium, nickel, and mercury data for the last year are estimates.

6-16
Flow of mercury in the environment

Based on *Materials balance and technology assessment of mercury and its compounds on national and regional bases*, EPA (Springfield, Va.: National Technical Information Service, 1975), EPA 560/3-75-007, pp. c, f, g.

Data do not include accidental releases or such unmeasured quantities as are released from coal-fired plants.

6-17
Cancer deaths associated with metals, 1940–1973

"Cancer mortality among cadmium production workers," Richard A. Lemen, et al. "Cancer mortality patterns in the lead industry," W. Clark Cooper. "Case study 4: Inorganic arsenic—Ambient level approach to the control of occupational carcinogenic exposures," Hector P. Blejer and William Wagner. *Annals of the New York Academy of Sciences: Occupational carcinogenesis* 271: 276, 254, 182 (1976).

Between 1940 and 1974, 292 white males with 2 or more years' employment in cadmium smelting were studied. Of 92 deaths, 27 were attributed to cancers.

Between 1947 and 1971, 2,352 lead smelter workers were studied. Of 342 deaths, 69 were attributed to cancers.

At the same time, 4,680 lead battery plant workers were studied. Of 1,014 deaths, 186 were attributed to cancers.

Arsenic workers involved in pesticide production between 1940 and 1972 were sampled. Of 173 deaths, 28 were attributed to cancers, 16 of them among workers whose exposure was less than 1 year.

189

Radiation

People have always been exposed to radiation from natural sources. But in the past 80 years, exposures have come from X-rays, other nuclear medicine procedures, nuclear power plants and nuclear materials processing, nuclear bomb fallout, and a growing variety of low-level sources that range from electric communication equipment and electronic devices to microwave ovens and smoke detectors.

Ionizing radiation, by definition, has sufficient energy to change the molecular structure of a biological system. Ionizing radiation may be either electromagnetic radiation (X-rays and gamma rays) or particulate radiation, which may be either electrically charged (alpha and beta particles) or may have no charge (neutrons).

Exposure to a sufficiently high dose of radiation, either as high-frequency electromagnetic waves or as high-velocity particles, can result in cell damage. It ranges from serious burns and rapid death for high-level exposure to genetic mutation and cancer for exposure to lower levels.

Radiation received by humans is measured in terms of the amount and kind that the body absorbs over time. One unit of absorbed radiation is a rem (roentgen equivalent man). A millirem (mrem), one-one thousandth of a rem, is the most commonly used measure for individual and population exposure. On the average, people in the United States receive 180 mrems per year. Because the damaging effects can build up over time, serious health problems may occur even though a single exposure would not be harmful.

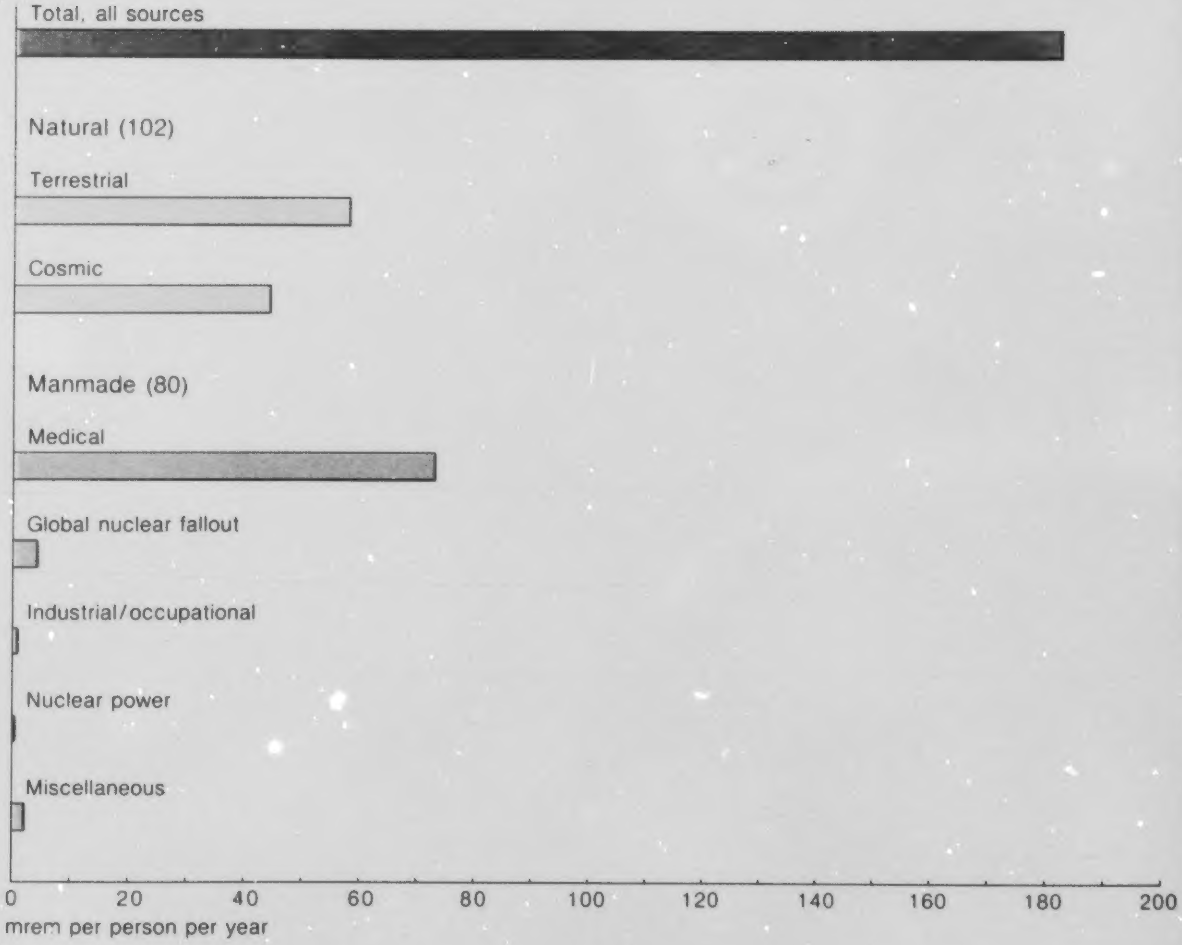
6-18
Radiation exposure, by source, 1970

Most exposure to radiation is from natural sources. The source of cosmic radiation is the sun and outer space; for terrestrial radiation, it is soils and rocks. Doses vary by altitude, latitude, and the amount of natural radioactive material present in the earth. Cosmic radiation, for example, is more than three times greater at altitudes of 10,000 feet than at sea level.

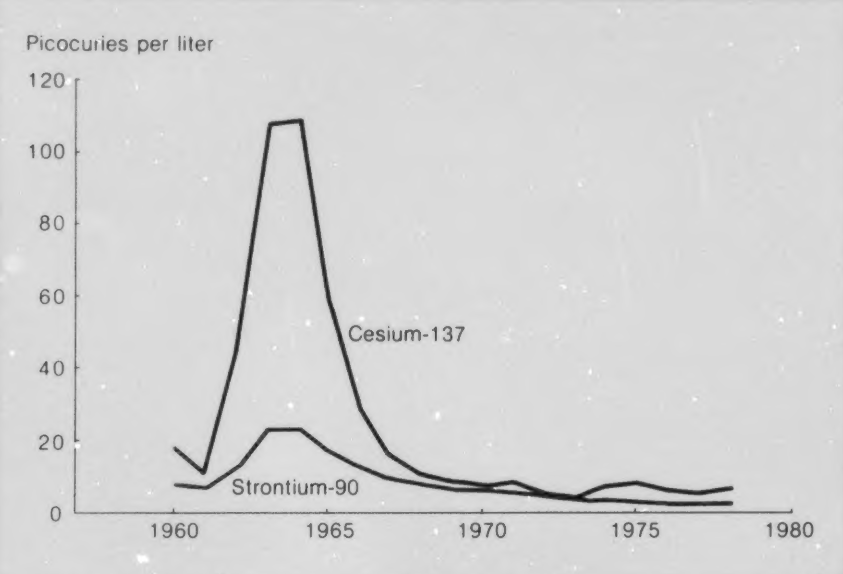
The largest source of manmade radiation comes from medical and dental X-rays and radioactive drugs. Exposure varies widely with the amount and type of procedures used. X-ray use increased by 2% to 3% per year during the 1950s and 1960s. Improved shielding techniques now in use are believed to have reduced medical exposure for the population as a whole.

Radiation from manmade sources other than medical-dental is very small compared to that from natural and medical sources. But growing amounts are being released at some sources—sources that are very important to specific groups of the population.

Exposure of the general population from all occupational sources is about 0.8 mrems per person per year; nuclear fallout, 4.0 mrems; nuclear power, 0.003 mrems; and all other (color TV receivers, air travel, consumer products, etc.), 2.0 mrems.


Total, all sources
Natural (102)
Terrestrial
Cosmic
Manmade (80)
Medical
Global nuclear fallout
Industrial/occupational
Nuclear power
Miscellaneous
0
20
40
60
80
100
120
140
160
180
200
mrem per person per year

6-19
Radiation levels from nuclear fallout, as measured by strontium-90 and cesium-137 in pasteurized milk, 1960-1978

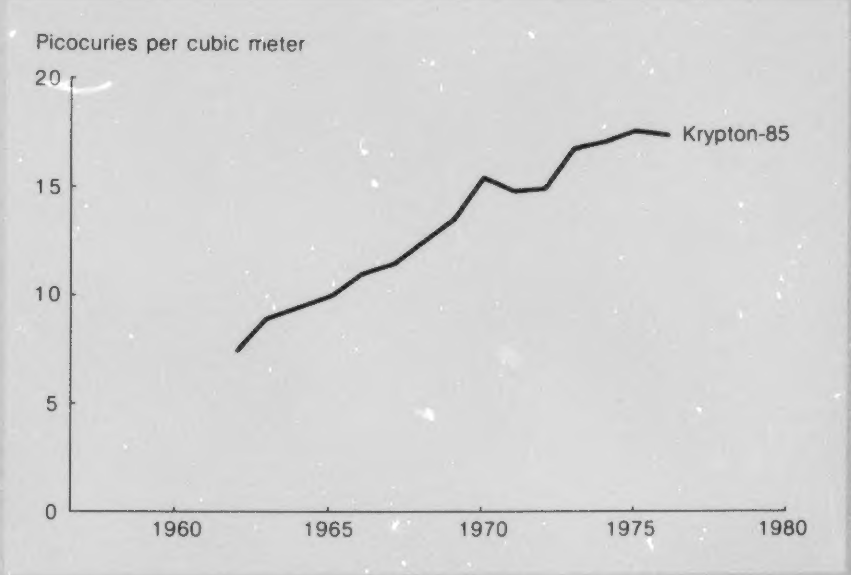


Two radionuclides deposited as fallout, cesium-137 and strontium-90, have been measured in pasteurized milk. They were released into the atmosphere from nuclear weapons testing, distributed worldwide, and then deposited. Levels have declined significantly from the early 1960s, when atmospheric testing of nuclear weapons peaked.

The current level of exposure from nuclear fallout is the result of high-yield atmospheric tests conducted by the United States and the USSR before 1964 and of the small amount added by more recent Chinese and French tests.

☐ Radionuclides are measured in picocuries per liter (pCi/l). A curie is a special unit of nuclear activity. One curie equals 3.7×10^{10} nuclear transformations per second. Pico indicates multiplication by one-trillionth (10^{-12}).

6-20
Radiation levels from nuclear power generation, as measured by krypton-85 in air, 1962–1976

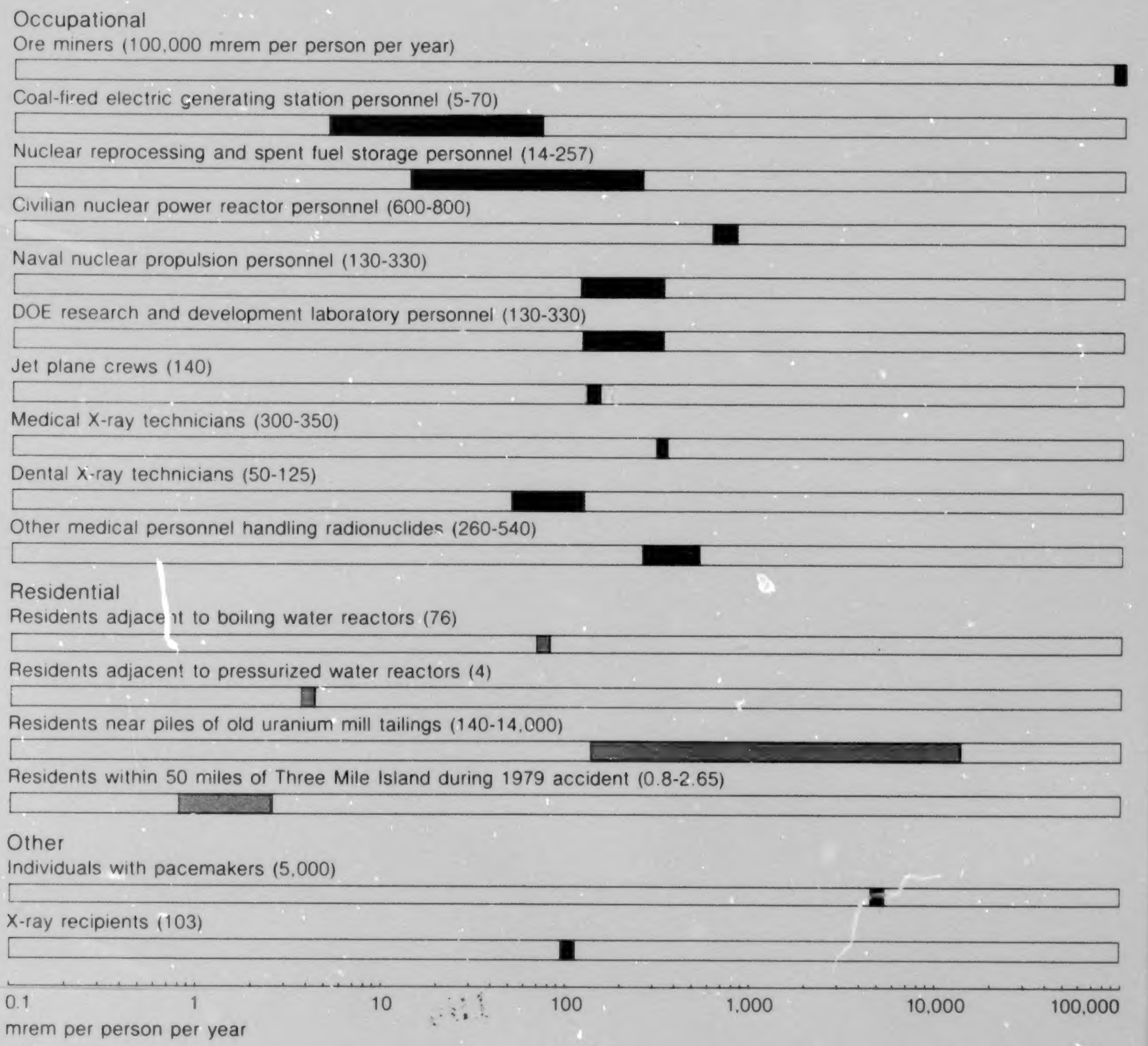


Exposure of the general population from nuclear power generation is very small, but it is growing. Krypton-85 is a long-lived radionuclide produced as a byproduct of the nuclear power industry. This form of radiation exposure has increased along with the use of nuclear power to generate more electricity. The rate of increase depends on the growth of the industry and on the technical and safety precautions taken.

Associated with nuclear power generation are uranium mining, uranium milling and fabrication, generating plant operation, and fuel processing and disposal. Mining and milling are not major contributors to total environmental radiation, but the amounts released locally, particularly radon-222 and its short-lived decay products, are a serious health hazard to uranium miners. Of great concern is the problem of nuclear waste disposal.

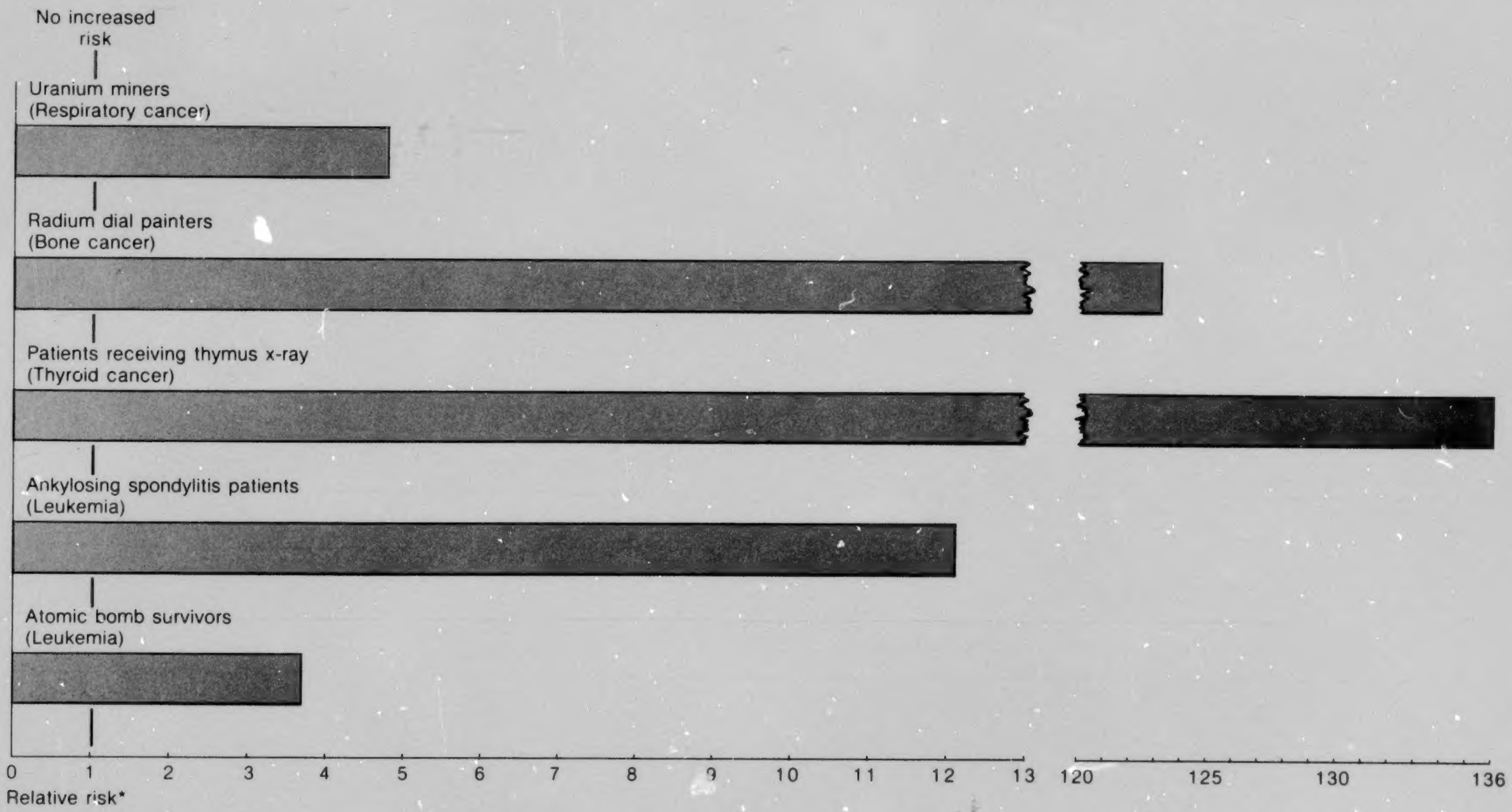
6-21

Radiation exposure of special population groups, 1970s



Special groups in the population are exposed to higher-than-average levels of radiation. For most of these individuals, the benefits of the product or service (heart pacemakers) or the job (jet pilot and crew, nuclear research and maintenance personnel) outweigh the risks involved, and for the most part, radiation levels are not dangerous. According to the Federal standard, exposure for individuals who work with radioactive materials is allowed to reach 5,000 mrems per year.

6-22
Relative risk of cancer from radiation, 1946–1974



*Relative risk is a ratio of risk similar to the standardized mortality ratio of death. The relative risk of cancer is the number of observed cases divided by the number of expected cases, taking into account sex and age differences.

197

198

For some groups, excessive exposure has created serious health problems, most notably, cancer.

Uranium miners working in an atmosphere with high levels of radon radiation had respiratory cancers almost five times the expected rate. The cancers were usually fatal.

A work group of the past, radium dial painters, contracted bone cancer 100 times more often than the general population.

Thyroid cancer, which is not usually fatal, was present at much higher levels than expected in individuals who had received radiation treatment for enlarged thymus glands.

Patients receiving high doses of radiation for ankylosing spondylitis, an extremely painful disease of the back, contracted a leukemia, which is nearly almost always fatal, at rates 12 times higher than expected.

Survivors of Hiroshima and Nagasaki, having received high levels of radiation in a single dose, were found to contract leukemia and other cancers at rates 3.7 times higher than they normally would have.

If radiation exposure of the U.S. population were to double, the most likely estimate of additional cancer deaths is 6,000 annually, an increase of approximately 2%.

The amount of radiation that can cause genetic defects is probably much lower than the amount that causes serious health effects. For this reason, most standards set by the Federal government for radiation exposure are for protection against genetic damage.

6-18
Radiation exposure, by source, 1970

Effects on populations of exposure to low levels of ionizing radiation, National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (Washington: USGPO, 1972), pp. 12, 19.

Exposure refers to the average annual whole-body dose rate expressed in rems or millirems. The rem is a unit of radiation dose equivalent. Individual doses are given in rems or millirems; population doses are in rems (i.e., person-rems).

Two recent studies raise problems with the 1972 estimate. See: *Report of the work group on radiation exposure reduction,* U.S. Department of Health, Education, and Welfare, Interagency Task Force on Ionizing Radiation (Washington, D.C., 1979). "The effects on populations of exposure to low levels of ionizing radiation," National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation, draft, June 1979.

The 1972 figure of 73 mrems per person per year for medical exposure is based in part on the 55 mrems per person per year received by the general population in 1964 from diagnostic X-rays. Using a different method of computation, the 1979 Committee reported 17 mrems per person per year for 1964 and 20 mrems for 1970.

The 1979 interagency report estimates the general population exposure from nuclear power in 1978 at 56,000 person-rems per year, approximately 0.26 mrem per person, which is far larger than the 0.003 mrem per person per year reported for 1972. The increase is a function of a change in measurement techniques rather than of a real change in radiation exposure.

6-19
Radiation levels from nuclear fallout as measured by strontium-90 and cesium-137 in pasteurized milk, 1960–1978

Environmental Protection Agency, Eastern Environmental Radiation Facility, Montgomery, Ala., unpublished data.

6-20
Radiation levels from nuclear power generation, as measured by krypton-85 in air, 1962–1976

1962–1969: Based on *Radiological quality of the environment in the United States, 1977,* EPA (Washington: USGPO, 1977), fig. 2-9, p. 44.

1970–1976: See 6-19.

6-21
Radiation exposure of special population groups, 1970s

Ore miners, coal-fired electric generating station personnel, nuclear reprocessing and spent-fuel storage personnel, residents adjacent to boiling water reactors, residents adjacent to pressurized water reactors, residents near piles of old uranium mill tailings, X-ray recipients, and individuals with pacemakers: *Radiological quality of the environment in the United States, 1977,* EPA (Washington: USGPO, 1977), pp. 5, 6, 7.

Civilian nuclear power reactor personnel, jet plane crews, naval nuclear propulsion workers, DOE research and development laboratory personnel, medical X-ray technicians, dental X-ray technicians, and other medical personnel handling radionuclides: "The effects on populations of exposure to low levels of ionizing radiation," National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation, draft, June 1979.

Residents within 50 miles of Three Mile Island during 1979 accident: *Population dose and health impact of the accident at Three Mile Island Nuclear Power Station,* U.S. Department of Health, Education, and Welfare, Ad Hoc Population Dose Assessment Group (Washington: USGPO, 1979), pp. 1, 2.

All exposures are expressed in mrem per person per year average whole-body dose unless otherwise specified. The doses for ore miners, coal-fired electric generating station personnel, nuclear reprocessing and spent-fuel storage personnel, and individuals with cardiac pacemakers are internal doses. The doses for residents adjacent to boiling and pressurized water reactors are external doses. The dose for residents near piles of old uranium mill tailings is a trachea-bronchial internal dose. The dose for X-ray recipients is the estimated mean active external bone marrow dose to adults in mrads per year.

Occupational exposure of special groups is estimated as follows: Civilian nuclear power industry, 30,000 persons; operation and maintenance of naval nuclear propulsion plants, 35,000; DOE research and development, 100,000; residents within 50 miles of Three Mile Island exposed between March 28 and April 7, 1979, 2 million; medical personnel handling radionuclides, 100,000; operators of medical X-ray equipment, 200,000; operators of dental X-ray equipment, 200,000.

6-22
Relative risk of cancer from radiation, 1946–1974

Uranium miners: "Respiratory disease mortality among uranium miners," Victor E. Archer, et al., *Annals of the New York Academy of Sciences: Occupational carcinogenesis* 271: 282, 284 (1976).

Radium dial painters, patients receiving thymus X-rays, ankylosing spondylitis patients, and atomic bomb survivors: *Effects on populations of exposure to low levels of ionizing radiation*, National Academy of Sciences, Advisory Committee on the Biological Effects of Ionizing Radiation (Washington: USGPO, 1972), pp. 129, 124, 117.

Data for uranium miners use a standardized mortality ratio divided by 100.

Between 1960 and 1974, 780 American Indian underground uranium miners were studied. Of 107 deaths, 17 were attributed to malignant neoplasms, of which 11 were from respiratory cancers. Between 1950 and 1974, 3,366 white male underground uranium miners were studied. Of 745 deaths, 206 were attributed to cancers, 144 of which were from respiratory cancers. Expected death rates for Indians were calculated from the male nonwhite population of Arizona and New Mexico; expected death rates for white miners were calculated from the male white population of the United States.

Between 1946 and 1971, 775 dial painters who had been exposed to doses of between 1 and 50,000 rads of radium-226 between 1915 and 1935 were studied; 48 developed a bone cancer.

In 1963, 2,878 patients who had been exposed in childhood to thymus X-rays between 1926 and 1957 were studied; thyroid cancers were surgically removed from 19.

In 1955, 11,287 ankylosing spondylitis patients exposed to radiation treatment between 1935 and 1954 at the age of 10 or older were studied in England and Wales; 32 developed a leukemia.

Of the survivors of the atomic bombs detonated at Hiroshima and Nagasaki in 1945, 19,472 were studied between 1951 and 1970; 62 who had been exposed at the age of 10 or older developed leukemia.

Chapter 7

Cropland, Forests, and Rangeland

Cropland, forests, and rangeland are working lands. For the most part, they are managed for the production of renewable resources: feed and food crops, timber, herbage, and browse. But other uses are becoming as important, to forests in particular—the support of wildlife, maintenance of watersheds, and provisions of recreation and aesthetic experiences.

How the lands are managed largely determines their quality—that is, the types of crops grown, the species of trees harvested and replanted, and the kinds, amounts, and methods of applying pesticides and fertilizers all affect the condition of the land. Attempts to increase agricultural production by using marginal lands and large amounts of chemicals can lead to water pollution, wildlife poisoning, land erosion, and overall land deterioration.

Some lands are under intense pressure for change in use. Prime farmland is being lost to rapidly expanding urban areas, and prime forest land is being cut, drained, and plowed for new cropland.

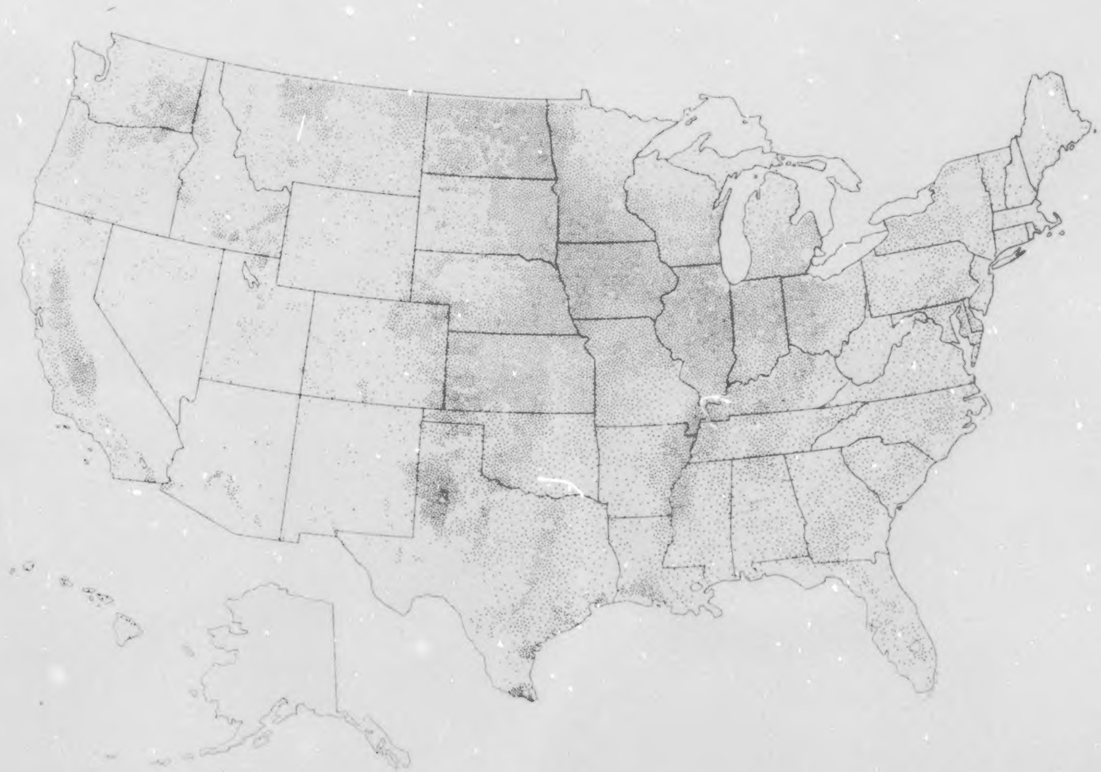
Cropland

The United States has more arable land than any other industrial nation and it produces enough food for some 290 million people.

Agricultural land is the most intensively managed of all nonurban lands. Use of large amounts of chemical nutrients and pesticides cause pollution in surface and ground waters. Poor tilling and harvesting practices have increased the rate of soil erosion. Excessive reliance on ground water for irrigation has depleted water supplies that take eons to replace.

Further, wetlands and other wildlife habitats are lost when they are converted for use as cropland. At the same time much prime farmland is taken out of production in favor of urban development and small-scale water projects.

7-1
Cropland



Each dot represents 25,000 acres

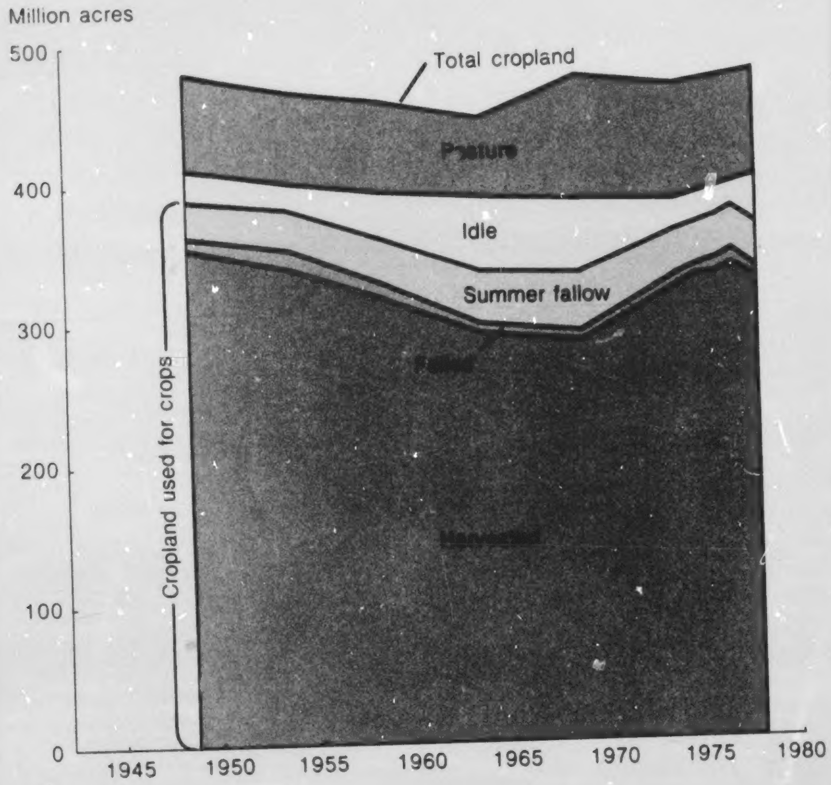
In 1974 cropland was estimated at 465 million acres. This total includes 361 million acres in crop rotation, 83 million acres in pasture, and 21 million idle.

The most intensively farmed States are Illinois and Iowa, where more than 70% of the land is in crops. Texas has the most cropland, 38 million acres, then Kansas with 32 million acres, North Dakota with 30 million, and Iowa with 28 million.

203

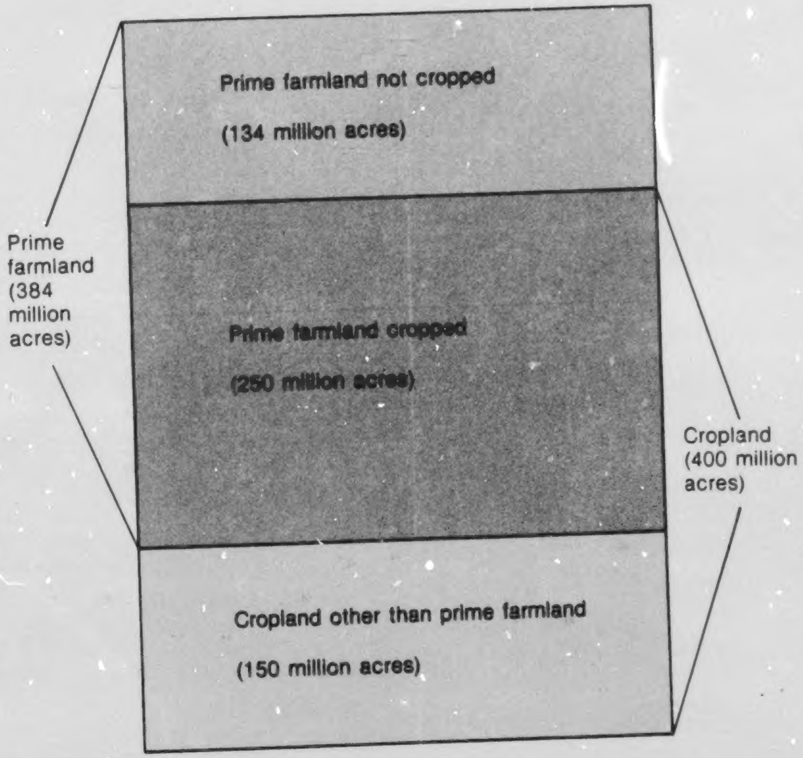
204

7-2
Uses of cropland, 1949-1978



The total cropland acreage, including pasture, has changed little in 30 years, but harvested cropland grew 14% between 1972 and 1975. This increase was due largely to the increased export demand for farm products, particularly wheat and soybeans.

7-3
Prime farmland, 1975


Prime farmland not cropped
(134 million acres)
Prime farmland cropped
(250 million acres)
Cropland other than prime farmland
(150 million acres)
Prime farmland (384 million acres)
Cropland (400 million acres)

Prime farmland is now being lost at an alarming rate. This is the land that is best suited for producing food, feed, forage, fodder, and oilseed. It produces the highest yields with minimum inputs of energy and money and with minimal damage to the environment.

Of the 384 million acres of prime farmland in the United States, 250 million are currently cropped. About 24 million acres could easily be converted to crops, and another 24 million acres would require some effort. To develop the remaining 86 million acres would require drainage, access roads, forest cutting, or other extensive and costly efforts.

7-4

Prime farmland lost to urbanization and water projects, by farm production region, 1967-1975

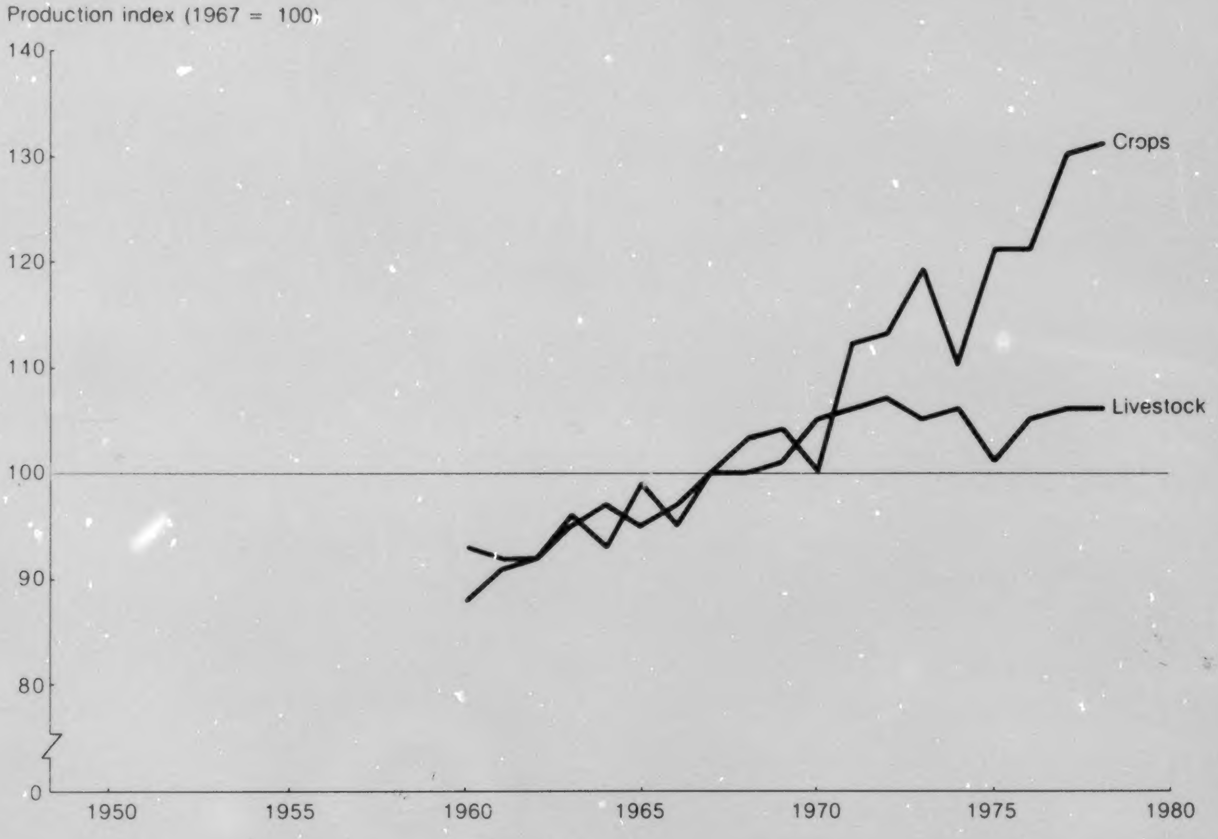
Percentage loss
More than 3.1%
3.1% or less
National average: 3.1%
m.a. = million acres lost

In the 8 years between 1967 and 1975, an average of 1 million acres of prime farmland was lost each year. About 6.5 million acres were lost to urbanization and 1.5 million to water projects. The most extensive losses were in the Southeast and the Corn Belt.

On a percentage basis, the loss of prime farmland was highest in the Southeast and the Northeast. Of great concern near metropolitan areas is the continuing loss of prime farmland that supplies fruits, vegetables, and other staples for local markets.

7-5

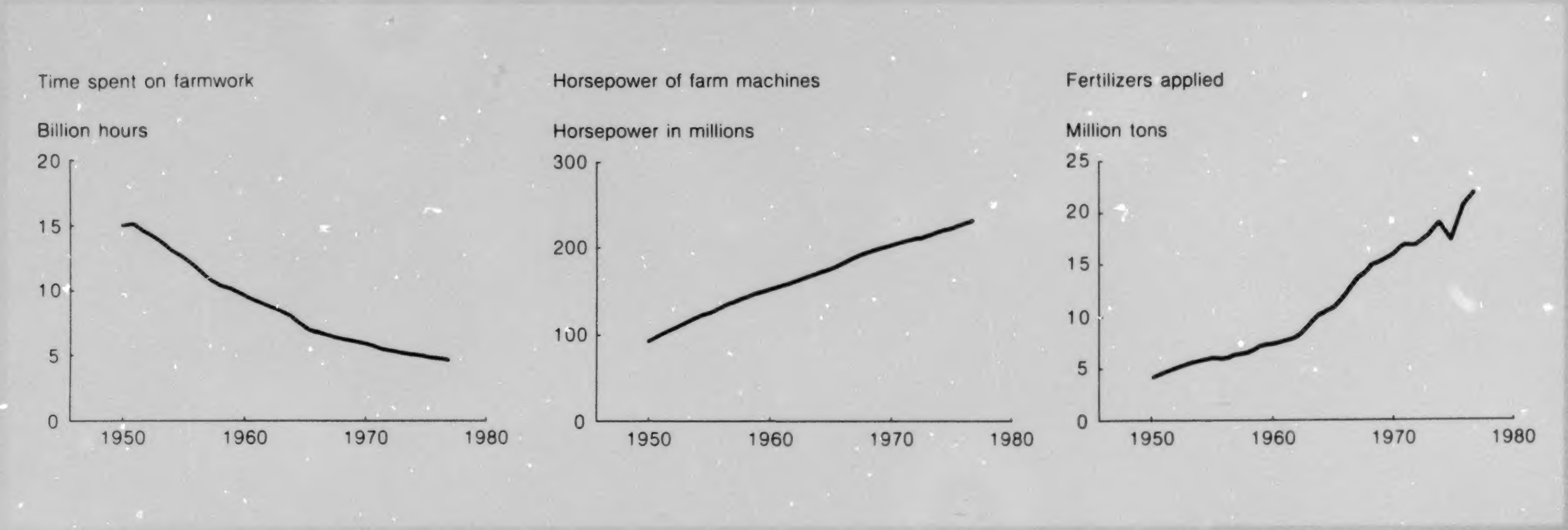
Agricultural production, 1960-1978



Farm output is at its highest level in history—about 20% above the base year 1967. Crop production has grown 30% in 10 years, with large increases in soybeans and other oil crops. Livestock production has remained relatively level. The large increase in poultry production has been offset by the decline in red meat animal production.

208

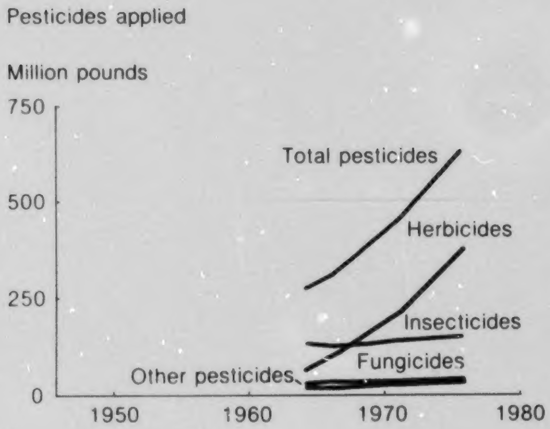
7-6
Agricultural inputs, 1950-1978



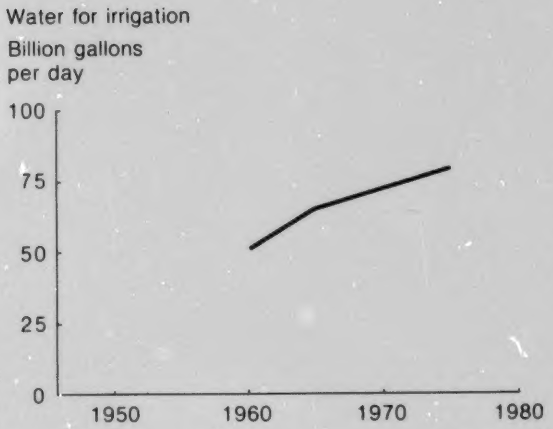
The growth in agricultural production is based on changes in the mix and productivity of agricultural inputs.

The number of hours spent on farmwork has declined sharply in response to the increasing use of farm machinery, in particular high-powered tractors, grain combines, and other mechanized implements.

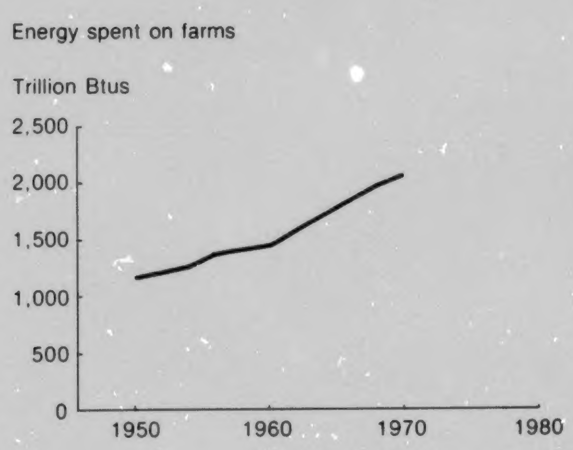
Fertilizer use more than quadrupled in 27 years, due mainly to the increased use of nitrogen compounds.



Farm pesticides—insecticides, fungicides, and herbicides—doubled between 1964 and 1976. Herbicide use on weeds increased the most.



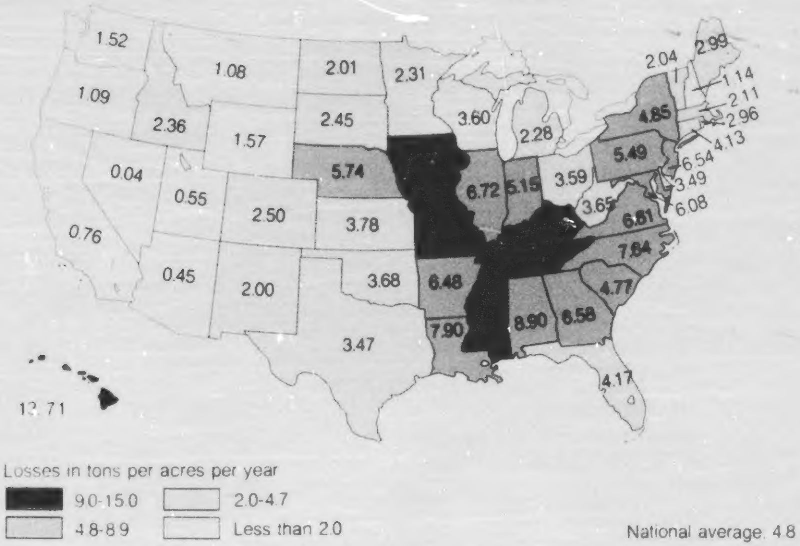
The amount of water used to irrigate cropland increased by more than 50% from 1960 to 1975. The area of irrigated cropland increased from 33 to 41 million acres, most of it in the western States.



Use of energy on the farm increased 73% from 1950 to 1970. Electricity use increased 94%, farm machinery use 167%, and fertilizer 292% in this time period.

7-7

Sheet and rill erosion from water on cropland, by State, 1977


1.52
1.09
1.08
2.36
0.04
0.76
0.55
0.45
1.57
2.50
2.00
2.01
2.45
5.74
3.78
3.68
3.47
2.31
3.60
6.72
5.15
2.28
3.59
3.65
6.48
7.90
8.90
6.58
4.77
7.64
6.81
5.49
4.85
2.04
2.99
1.14
2.11
2.96
4.13
6.54
3.49
6.08
4.17
13.71
Losses in tons per acres per year
9.0-15.0
4.8-8.9
2.0-4.7
Less than 2.0

National average: 4.8

The most serious problem in maintaining good cropland is loss of topsoil. Erosion is a natural process whereby water, wind, or other erosive elements remove soil or rock from the land. Wind and water erosion not only reduces productivity but it is depleting one of the Nation's most important natural resources.

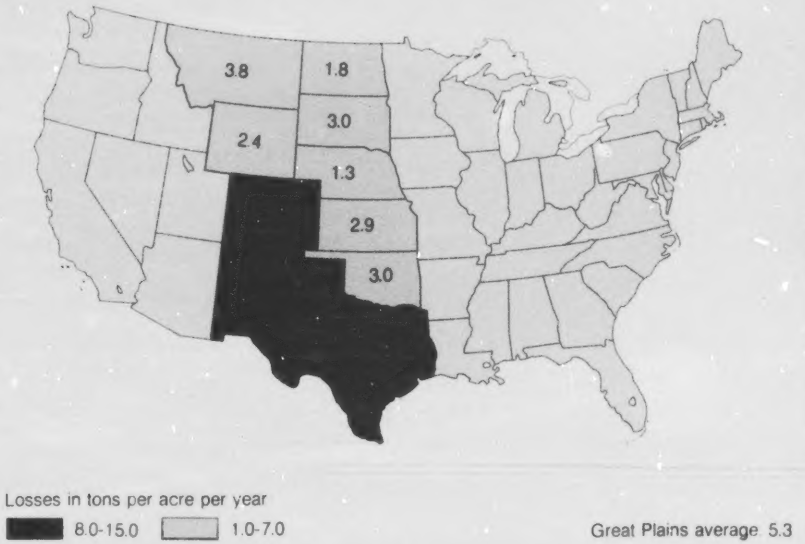
The average annual sheet and rill erosion in 1977 was 4.8 tons per acre for all croplands. The rate was 5.4 tons on cultivated land, excluding that in sod crops and other special cover. The areas most seriously affected are in Tennessee, Kentucky, Missouri, Louisiana, Mississippi, and Iowa.

Under normal conditions, topsoil is replaced at the rate of 1.5 tons per acre per year. Any loss from cropland that exceeds 1 to 4 tons per acre per year, depending on soil depth, is considered serious because production cannot be sustained. If eroding conditions persist, the complete layer of topsoil may be lost. An estimated 200 million acres of cropland have been permanently damaged, and another 241 million acres—over one-half of all cropland—is in need of conservation treatment.

☐ Sheet erosion occurs when beating rain and flowing water remove layers of soil from fields. Rill erosion occurs as the flowing water carves out channels.

7-8

Wind erosion on cropland in the Great Plains States, 1977


3.8
1.8
3.0
2.4
1.3
2.9
3.0
Losses in tons per acre per year
8.0-15.0
1.0-7.0

Great Plains average: 5.3

According to the Soil Conservation Service, "[w]ind erosion is caused by a strong turbulent wind blowing across an unprotected soil surface that is smooth, bare, loose, dry, and finely granulated. . . . [It] usually begins on exposed knolls, in tracks or paths made by implements or animals, and in turn rows where the vegetation and surface soil have been pulverized." Most of the damage from wind erosion occurs in the Great Plains States, notably Colorado, New Mexico, and Texas. The annual movement of soil per acre of cropland for these States averages 8.9, 11.5 and 14.9 tons, respectively.

☐ Estimates of soil loss due to wind erosion are not available for other than the 10 Great Plains States.

Sources and technical notes

7-1
Cropland

The national atlas of the United States of America, U.S. Geological Survey (Washington, D.C., 1970), p. 160.

Map shows cropland area for 1964.

Several Federal agencies estimate cropland acreages for the mid-1970s.

The *1974 census of agriculture* estimates cropland at 440 million acres in 1974.

The Crop Reporting Board, USDA Economics, Statistics, and Cooperatives Service, estimates cropland including pasture at 465 million acres in 1974.

The Inventory and Monitoring Division, USDA Soil Conservation Service, estimates non-Federal cropland at 400 million acres, excluding Alaska and Hawaii, in 1975.

7-2
Uses of cropland, 1949-1978

Our land and water resources, USDA Economic Research Service (Washington: USGPO, 1974), misc. pub. 1290, p. 4.

Major uses of land in the United States: 1974, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1979), agr. econ. rep. 440, p. 9.

USDA Economics, Statistics, and Cooperatives Service, unpublished data.

1978 data for idle cropland and pasture are preliminary.

7-3
Prime farmland, 1975

"A perspective on prime farmland," Keith O. Schmude, *J. Soil & Water Conserv.* 32:241 (1977).

7-4
Prime farmland lost to urbanization and water projects, by farm production region, 1967-1975

See 7-3, pp. 241, 242.

Estimates for USDA Soil Conservation Service regions of prime farmland include non-Federal land only and exclude Alaska and Hawaii.

7-5
Agricultural production, 1960-1978

1960-1963: *Agricultural statistics 1975*, U.S. Department of Agriculture (Washington: USGPO, 1975), table 618, p. 440.

1964-1978: *Agricultural statistics 1979*, U.S. Department of Agriculture (Washington: USGPO, 1979), table 633, p. 440.

Data for 1978 are preliminary.

7-6
Agricultural inputs, 1950-1978

Time spent on farmwork: *Changes in farm production and efficiency, 1977*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1978), statistical bulletin 612, p. 32.

Horsepower of farm machines: *Changes in farm production and efficiency, 1977*, p. 31.

Fertilizers applied: *Changes in farm production and efficiency, 1977*, p. 27.

Pesticides applied, 1964: *Quantities of pesticides used by farmers in 1964*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1968), agr. econ. rep. 131, pp. 9, 13, 19, 26. 1966: *Farmers' use of pesticides in 1971—Quantities*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1974), agr. econ. rep. 252, pp. 8, 11, 15, 18. 1971 and 1976: *Farmers' use of pesticides in 1976*, USDA Economics, Statistics, and Cooperatives Service (Washington: USGPO, 1978), agr. econ. rep. 418, pp. 6, 9, 15, 20.

Water for irrigation: *Estimated use of water in the United States in 1975*, U.S. Geological Survey (Washington: USGPO, 1977), circ. 765, p. 38, and previous quinquennial surveys.

Energy spent on farms: *The U.S. food and fiber sector: Energy use and outlook*, USDA Economic Research Service (Washington: USGPO, 1974), p. 2.

Btus converted from kilocalories (kcal), as published in "Energy use in the food system," J.S. and C.E. Steinhart, *Science* 184:309 (1974). (1 kcal = 3.968 Btus; 1 Btu = 0.252 kcal.)

Time spent on farmwork includes crops, livestock, and overhead. After 1964, time used for horses, mules, and farm gardens was excluded.

Horsepower includes tractors only (exclusive of steam and garden).

Fertilizers include nitrogen, phosphate, and potash nutrients used.

Pesticides include amounts used on crops only; excludes pesticide use for livestock and other purposes.

Water used for irrigation refers to water consumed, not water withdrawn.

Energy spent on farms includes fuel, electricity, fertilizer, agricultural steel, farm machinery, tractors, and irrigation.

7-7
Sheet and rill erosion from water on cropland, by State, 1977

USDA Soil Conservation Service, 1977 National Erosion Inventory Estimates, unpublished computer printout, December 1978 table J1.

Estimates include non-Federal cropland only and exclude Alaska and Hawaii.

7-8
Wind erosion on cropland in the Great Plains States, 1977

See 7-7, table K1.

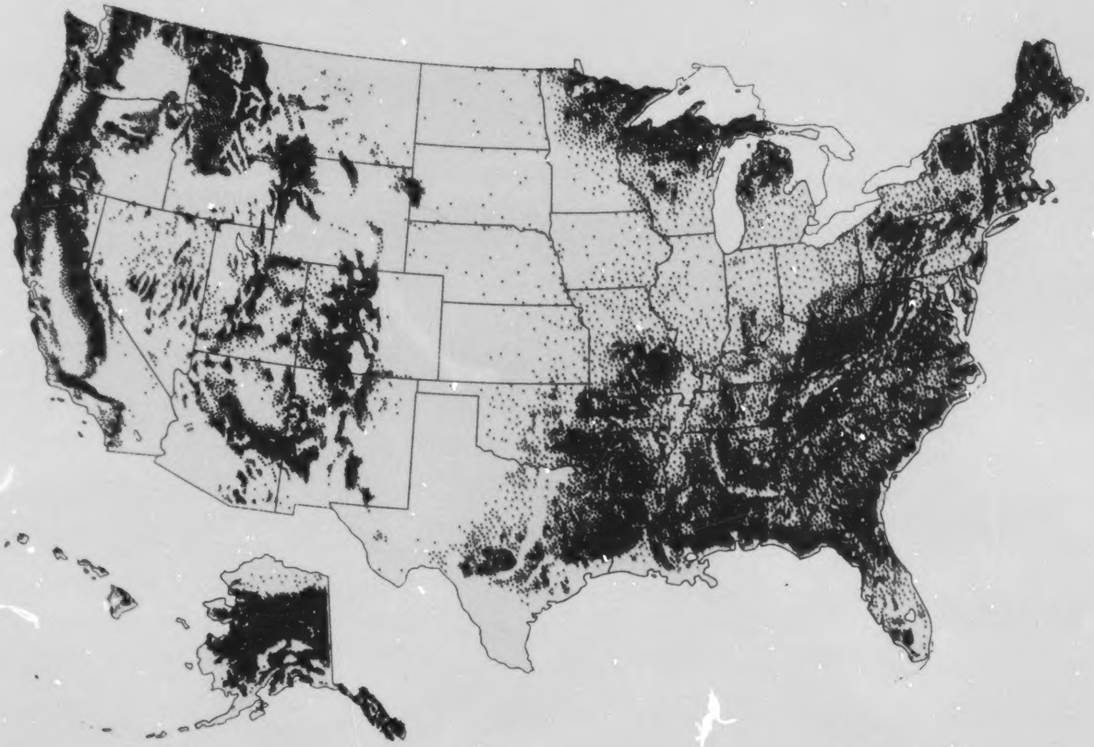
Estimates include non-Federal cropland only.

Forests

Forests range from extensive tracts of virgin timber in the Pacific Northwest and Alaska to the white pine and oak-hickory forests of the East that are still growing back after settlers and early industrialists cut them for agriculture, firewood, and building material.

The most common use of these lands is for timber, but some are managed and protected for other uses as well—recreation, wildlife habitat, watershed protection, livestock forage, and wild areas.

7-9
Forests

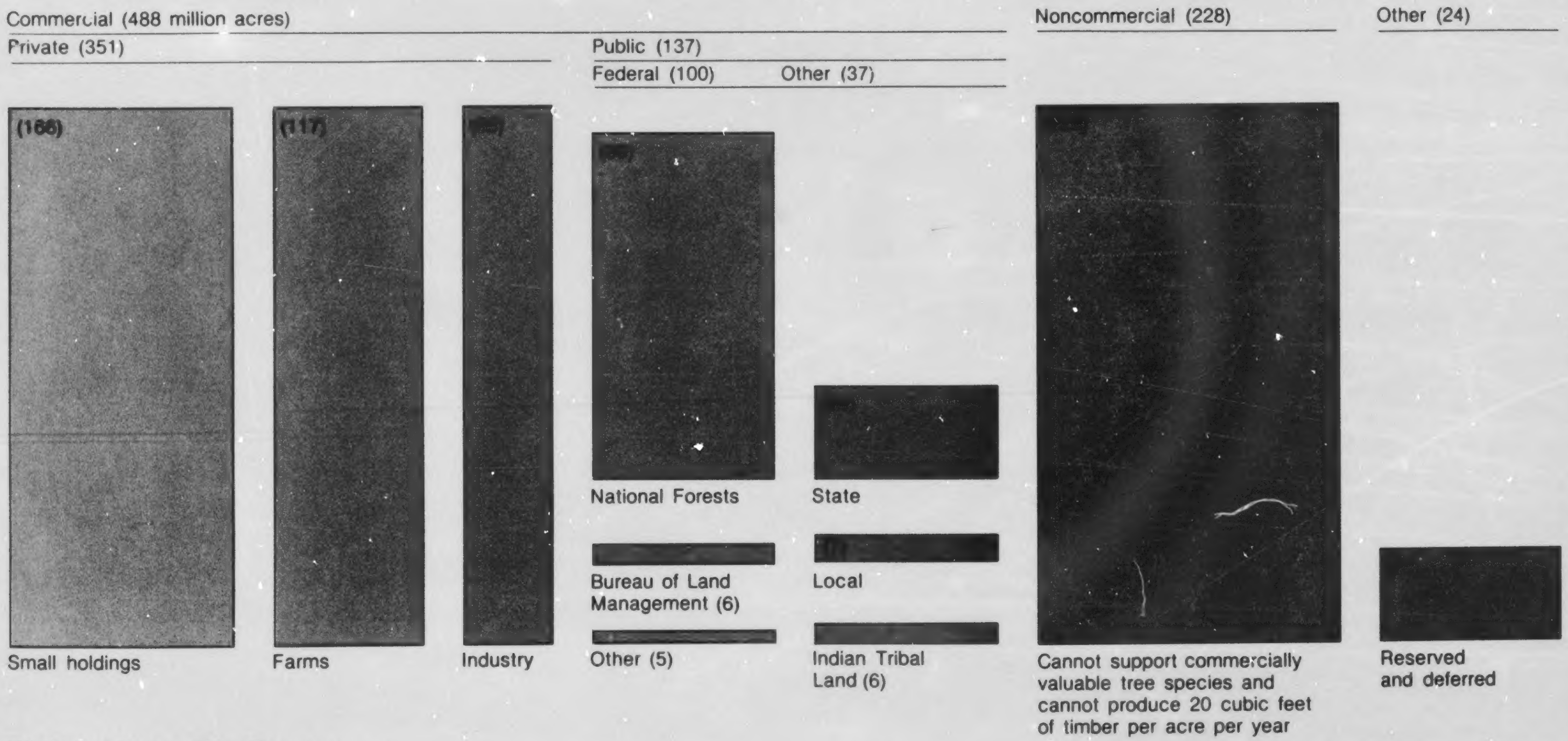


Each dot represents 25,000 acres

The United States contained 740 million acres of forest land in 1976, about a third of its total land area. To be classified as forest land, at least 10% must be or have been stocked by forest trees of any size and must not currently be developed for nonforest use.

7-10

Ownership of forest land, 1977



Total forest land = 740 million acres

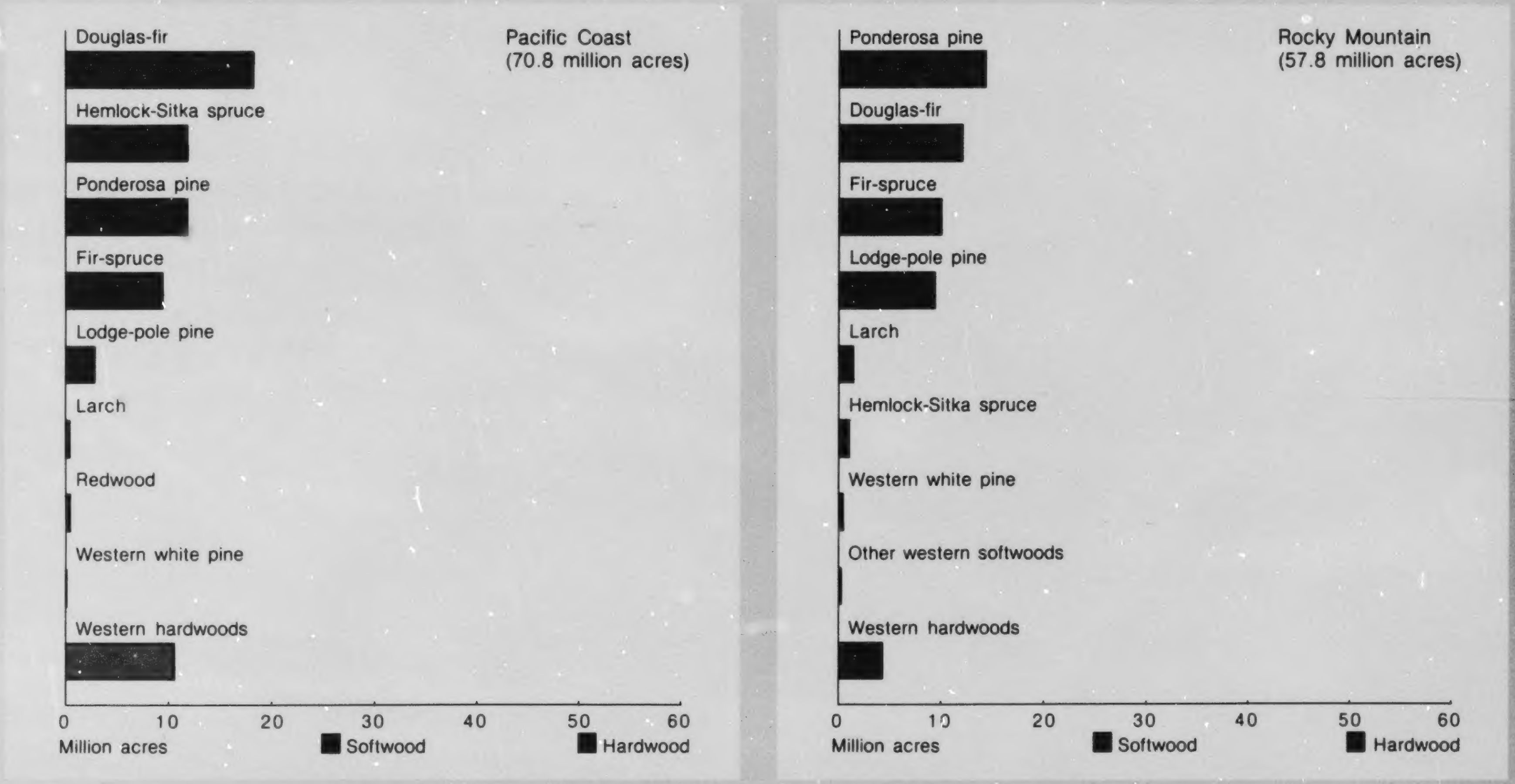
Two-thirds of all forest land is "commercially" productive—that is, it is capable of growing economically valuable tree species in excess of 20 cubic feet per acre per year. The remaining third is noncommercial; is reserved for parks, wildlife habitat, recreation areas, and wilderness; or is deferred and may be under study for wilderness designation.

Most commercial forest land is in private small holdings and farms.

The National Forests contain about 18% of all commerical forests.

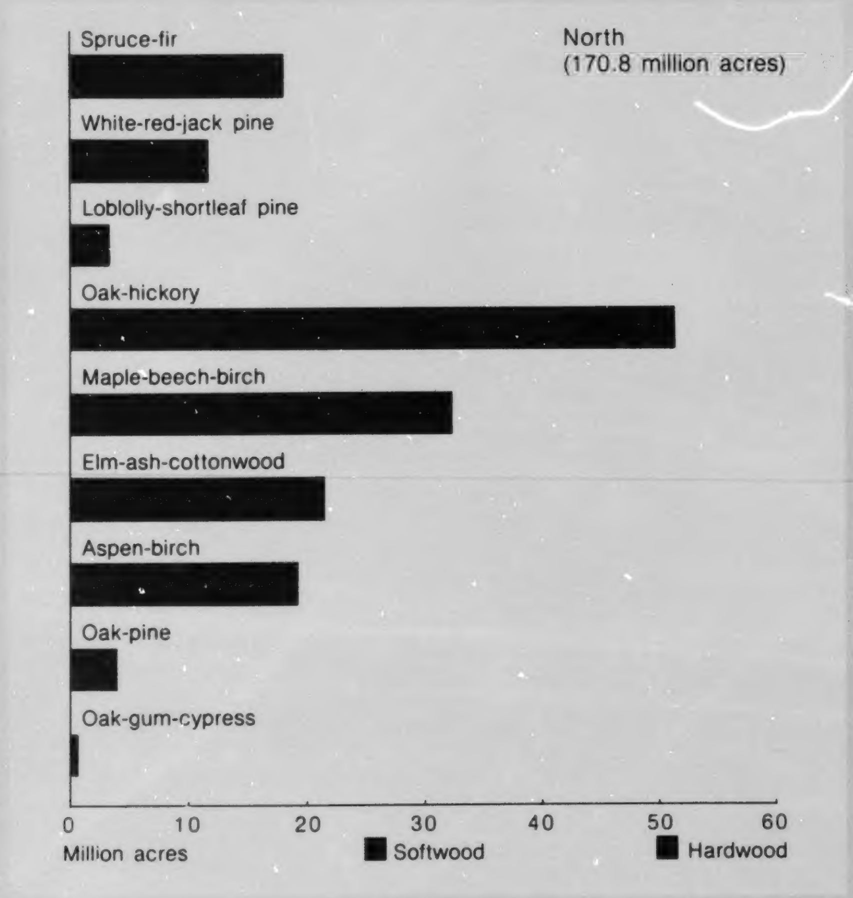
☐ Reserved and deferred (24 million acres) is commercial forest land that is exempted from timber uses. Most of this is in Federal National Forest land.

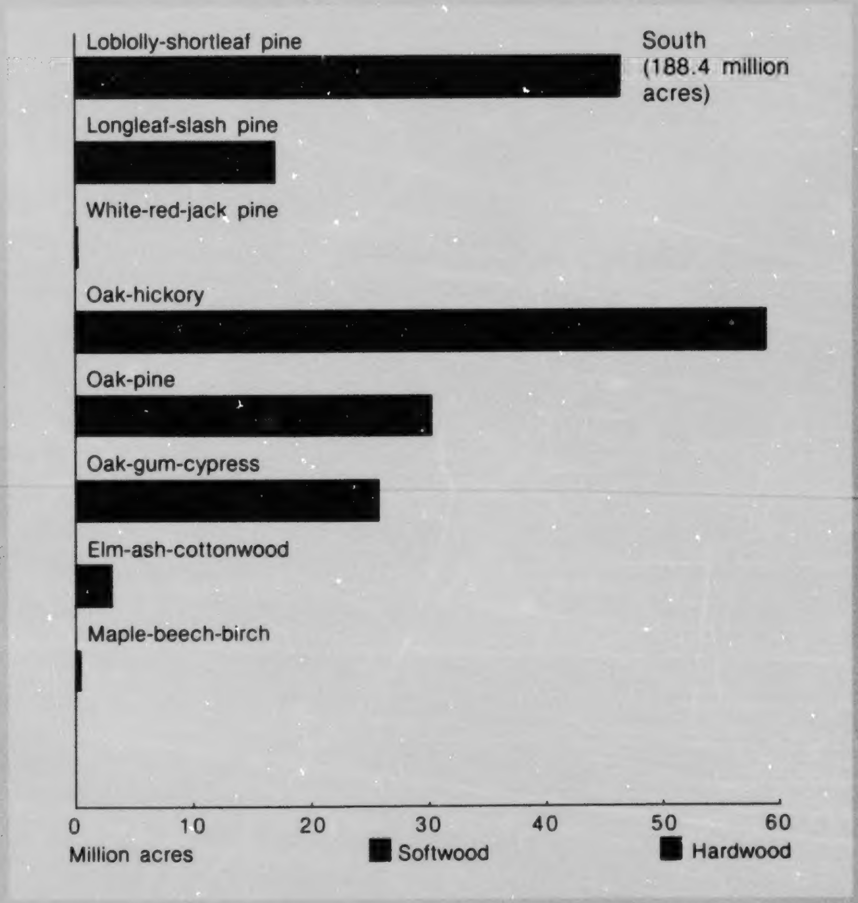
7-11
Commercial forest land, by region and ecosystem, 1977



Forest land may be classified by type of vegetation. An oak-hickory ecosystem, for example, contains a stand of trees in which the largest percentage is oak or hickory.

Hardwoods are usually broadleafed and deciduous. Most hardwood forests are in the North and South. Softwoods are conifers, usually evergreens, with needles or scale-like leaves. Softwood forests grow in the Pacific and Mountain regions, but the South also contains large acreages of pine.


North
(170.8 million acres)
Spruce-fir
White-red-jack pine
Loblolly-shortleaf pine
Oak-hickory
Maple-beech-birch
Elm-ash-cottonwood
Aspen-birch
Oak-pine
Oak-gum-cypress
0
10
20
30
40
50
60
Million acres
■ Softwood
■ Hardwood


South
(188.4 million acres)
Loblolly-shortleaf pine
Longleaf-slash pine
White-red-jack pine
Oak-hickory
Oak-pine
Oak-gum-cypress
Elm-ash-cottonwood
Maple-beech-birch
0
10
20
30
40
50
60
Million acres
■ Softwood
■ Hardwood

Forest Service Regions
Pacific Coast
Rocky Mountain
North
South

SS 222

SS 223

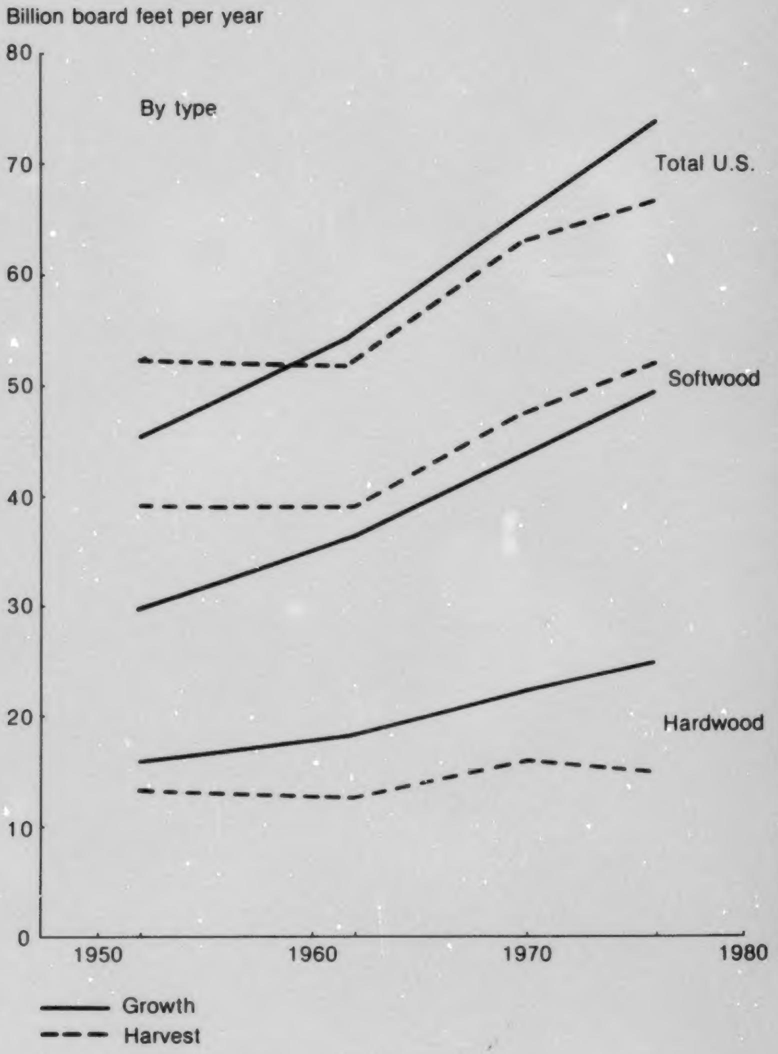
7-12
Sawtimber growth and harvest, by type, 1952-1976

A major use of commercial forest land is timber production.

Sawtimber growth on commercial forest land has been increasing steadily. Between 1952 and 1976 the total timber growth increased 64% although the acreage was decreasing. At the time, the harvest increased from 52 billion to 66 billion board feet.

Softwoods are in far greater demand than hardwoods. As a result, annual harvest of softwood has consistently exceeded annual growth.

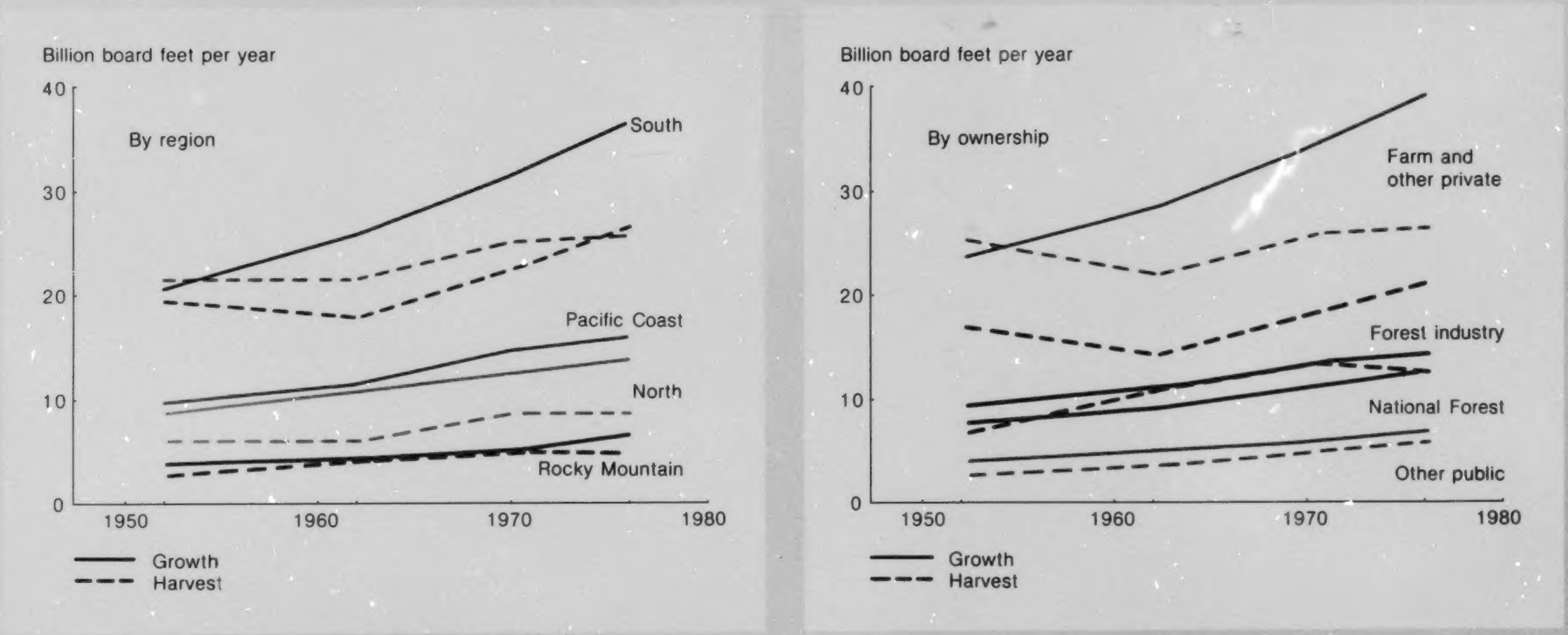
Roughly 20% more sawtimber is grown but is lost to wildfires, insects, and disease.



.SS

224

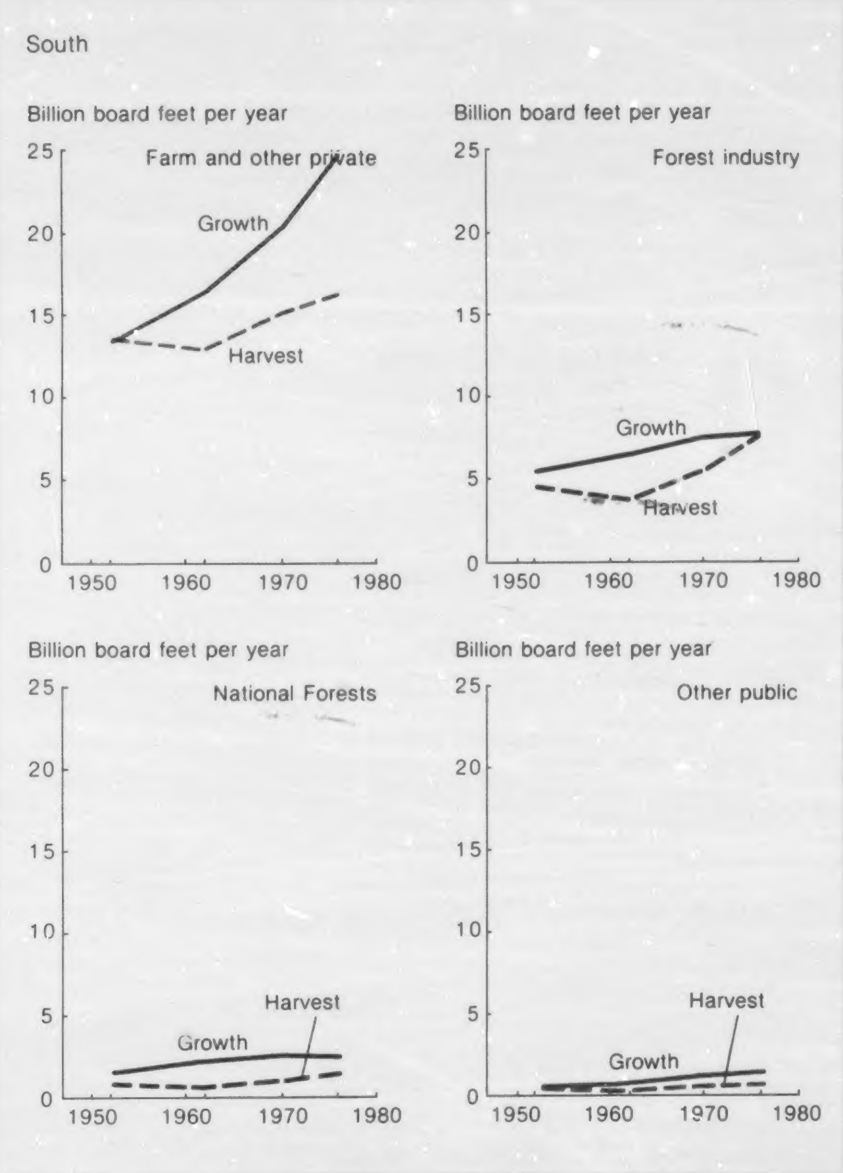
7-13
Sawtimber growth and harvest, by region and ownership, 1952-1976

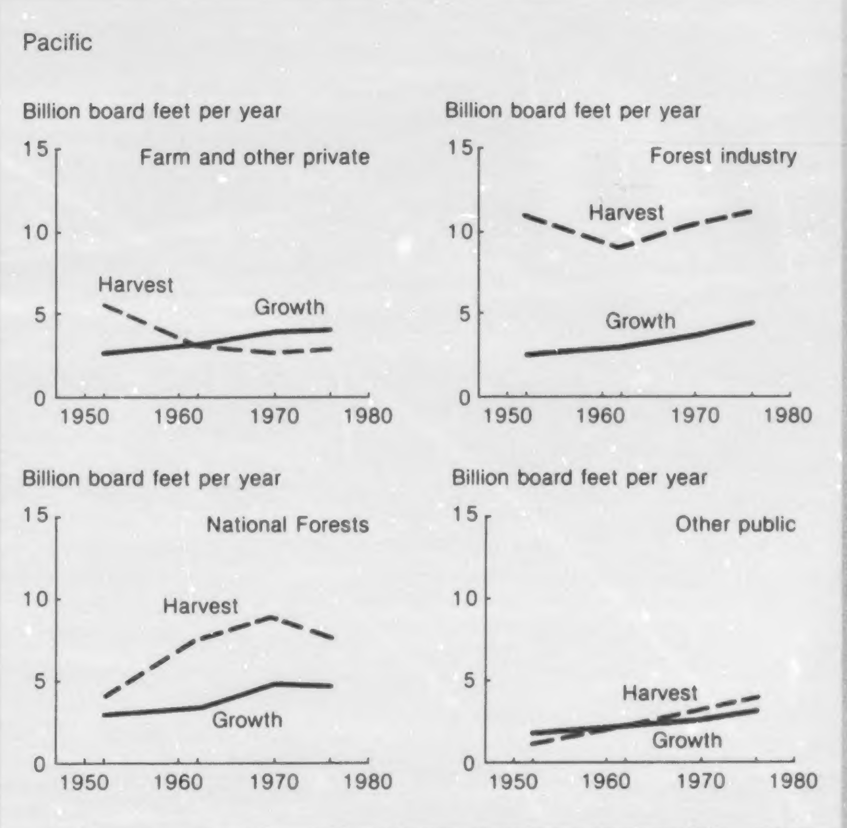


Almost 80% of all the timber is harvested in the Pacific Coast and the South.

Most of the timber harvest is on small farms or wood lots and other private non-industrial lands. Yet, since 1962, the largest increases in harvest have been on forest industry lands, which are consistently cut at a rate that exceeds the growth.

7-14
Sawtimber growth and harvest in two regions, by ownership, 1952-1976



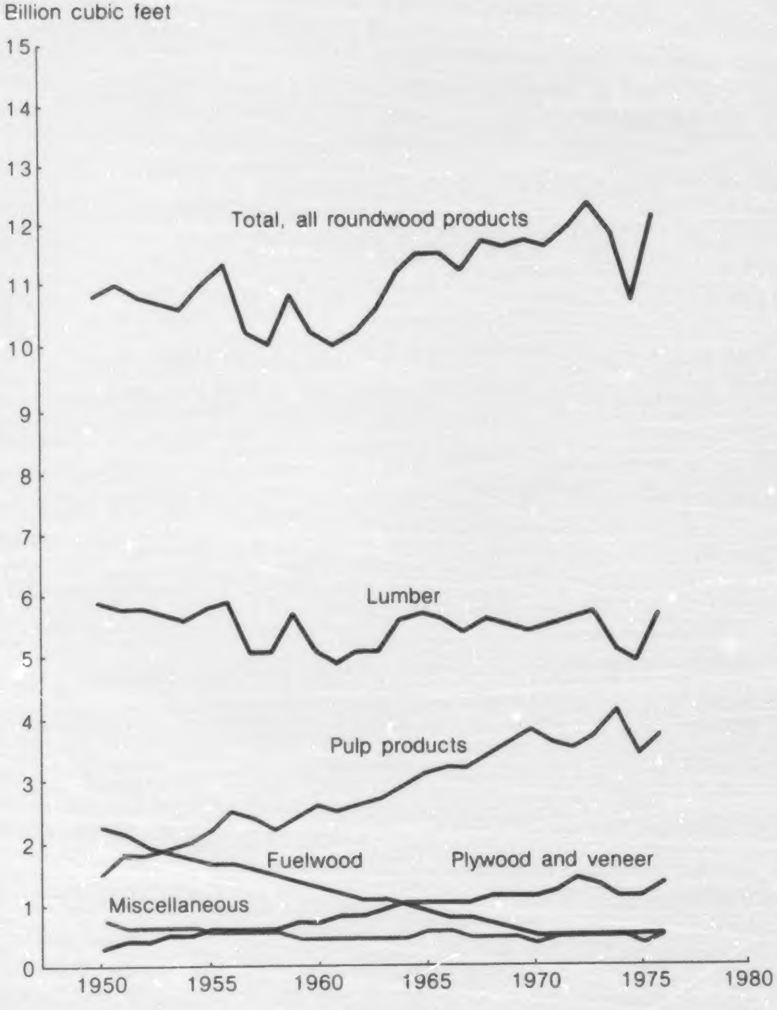


In the South, the harvest on small private holdings reached 16.5 billion board feet in 1976—25% of the national timber harvest.

Forest industry lands on the Pacific Coast are being harvested at more than twice the rate of growth. Much of this harvest is virgin Douglas-fir.

7-15

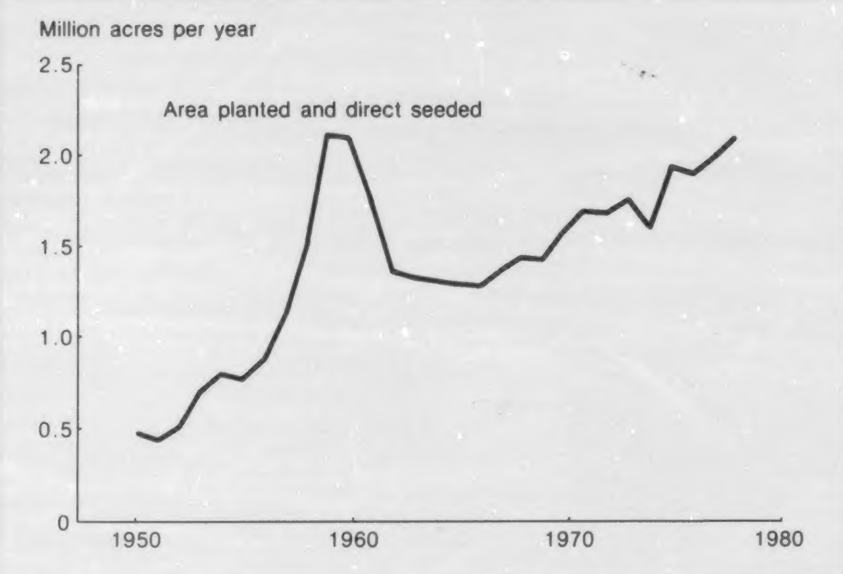
Roundwood harvest, by product, 1950-1976

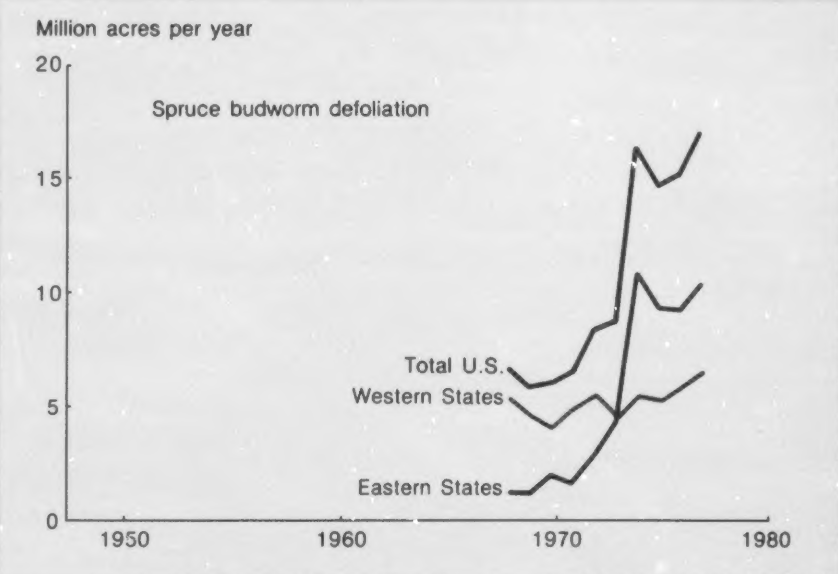


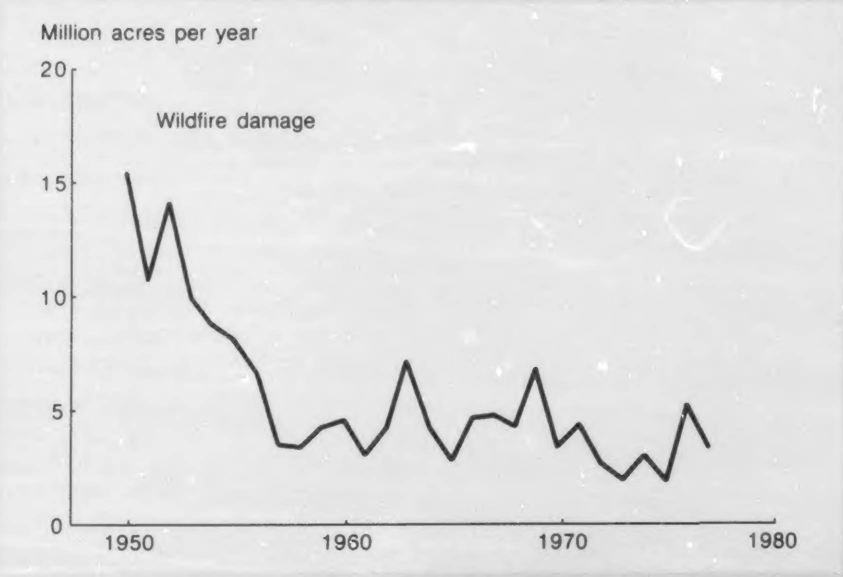
In 26 years, the amount of roundwood cut for lumber has remained relatively constant, but the amount cut for pulpwood (used in newsprint and other paper, cardboard, and other intermediate and final products) has increased steadily. About 0.5 billion cubic feet, 4% of the roundwood harvest, was used for fuel in 1976, compared to 21% in 1950.

Since the early 1900s, the United States has imported more timber products than it exported. In 1972, net imports were 1.6 billion cubic feet, which is 11% of consumption—double the 1950 level. Most imports are pulpwood from Canada.

7-16
Forest conditions, 1950-1978







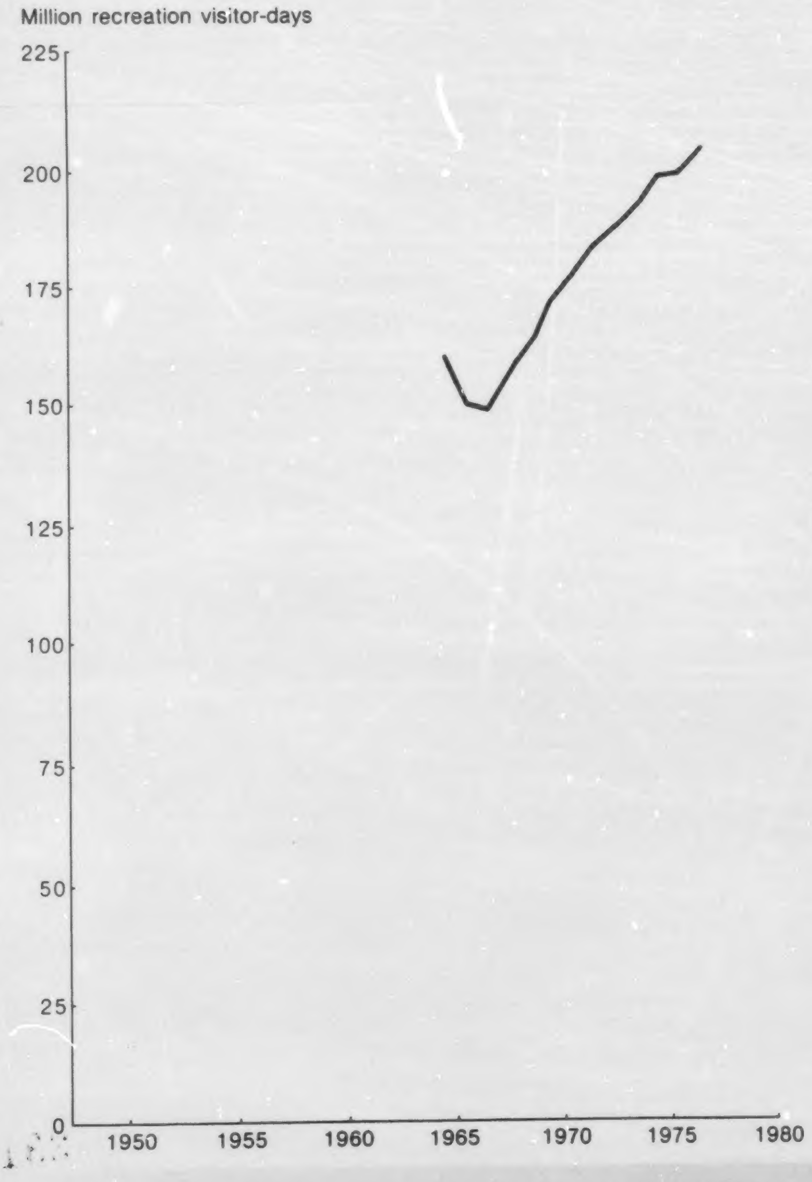
The condition of a forest depends on the amount and type of harvesting; extent and methods of replanting after harvest; control of wildfires, diseases, and insects; severity of soil erosion; use for recreation; and other factors.

Reforestation is increasing. The average number of acres planted per year during the 1970s was 1.8 million—about 20% higher than in the 1960s.

Wildfire now destroys more than 3 million acres of forest each year, but this loss is much less than in the first half of the century, when fire often destroyed more than 10 million acres in a given year.

More timber damage is caused by insects and disease than by fire. About 17 million acres of forest land were defoliated in 1977 by the spruce budworm, perhaps the single most destructive forest pest. Defoliation reduces growth and sometimes kills the tree.

7-17
Recreational use of the National Forests, 1965-1977

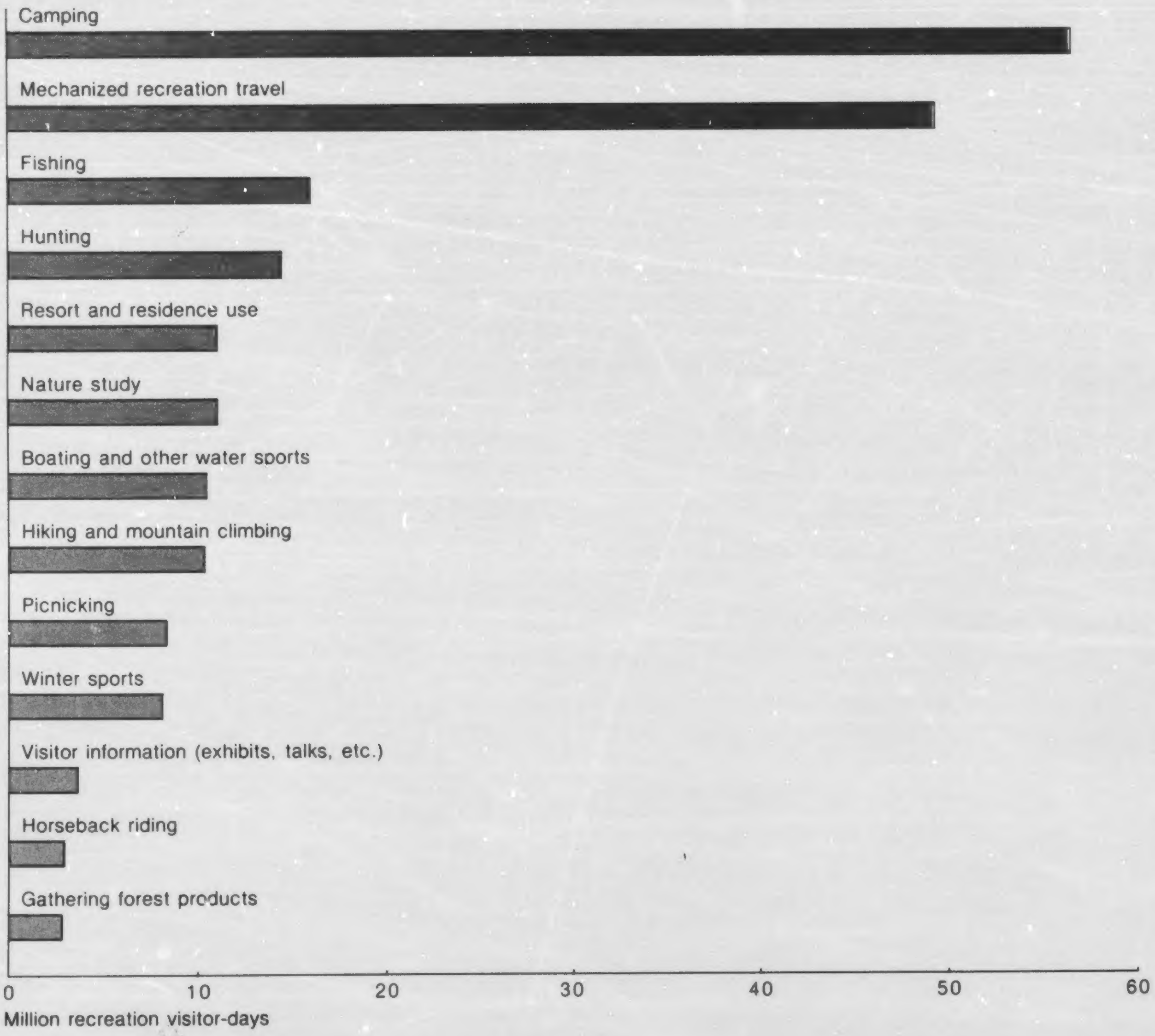


The 154 National Forests are managed for multiple uses that include wildlife preservation, watershed protection, and recreation, in addition to the growth of commercial timber.

The number of visitors to the National Forests has been increasing at an average rate of 5 million per year since 1967.

☐ A visitor day is 12 person-hours. It involves one person for 12 hours, 12 persons for one hour, or any equivalent combination of individual or group use, either continuous or intermittent.

7-18
Recreational use of the National Forests, by activity, 1977



In 1977, about two-thirds of all visitor days were spent in dispersed locations—hunting, fishing, driving for pleasure, etc. The remaining one-third of visitor days were spent at developed sites—picnic grounds, resorts and residences, marinas, etc.

7-9
Forests

The national atlas of the United States of America, U.S. Geological Survey (Washington, D.C., 1970), p. 160.

Map shows forest area for 1959.

7-10
Ownership of forest land, 1977

Forest statistics of the United States, 1977, USDA Forest Service (Washington: USGPO, 1978), tables 1, 2, pp. 2, 8.

All data are preliminary.

7-11
Commercial forest land, by region and ecosystem, 1977

See 7-10, tables 4, 5, pp. 12, 17.

All data are preliminary. They exclude 18 million acres of nonstocked forest areas.

Forest types describe associations of tree species, which in turn reflect factors of site, climate, and stand history.

The forest ecosystems presented are combinations of more than 80 local forest types traditionally used for forest management purposes.

Commercial forest land is land which produces or is capable of producing commercial timber and has not been withdrawn from timber use. Areas must be able to produce more than 20 cubic feet of timber per acre per year.

7-12
Sawtimber growth and harvest, by type, 1952-1976

See 7-10, tables 34, 35, pp. 84, 86.

All data are preliminary.

Sawtimber refers to live trees of commercial species containing at least one 12-foot saw log or two noncontiguous 8-foot logs.

The minimum diameter for softwood is 9 inches, except in the West where it is 11 inches. For hardwood it is 11 inches.

Board feet is a standard measure of 12" × 12" × 1" or its equivalent for sawtimber and lumber.

Growth is the annual change in volume of sound wood in live sawtimber trees resulting from natural causes.

Harvest is the net volume of growing stock trees removed from the inventory by harvesting, cultural practices, land clearing, and change in land use.

7-13
Sawtimber growth and harvest, by region and ownership, 1952-1976

See 7-10, pp. 83–86.

A farm is a place of 10 or more acres from which the annual sale of agricultural products totaled $50 or more or a place of less than 10 acres from which the sale of agricultural products totaled $250 or more during the previous year.

Other private lands are privately owned lands other than forest industry, farmer-owned, or corporate lands.

Forest industry lands are owned by companies or individuals operating wood-using plants.

National Forests have been so designated by Executive Order or statute and are under the administration of the USDA Forest Service.

Other public lands include all publicly owned lands other than National Forests.

7-14
Sawtimber growth and harvest in two regions, by ownership, 1952-1976

See 7-10, pp. 83–86.

7-15
Roundwood harvest, by product, 1950-1976

The demand and price situation for forest products, 1976–1977, USDA Forest Service (Washington: USGPO, 1977), table 2, p. 39.

Data for 1973–1976 are preliminary.

Roundwood products are logs, bolts, and other round sections cut for industrial and consumer use.

Miscellaneous products include cooperage logs, poles and piling, fenceposts, hewn ties, round mine timbers, box bolts, excelsior bolts, chemical wood, shingle bolts, and miscellaneous items.

7-16
Forest conditions, 1950-1978

Area planted and direct seeded, 1950–1970: *The outlook for timber in the United States*, USDA Forest Service (Washington: USGPO, 1974), forest res. rep. 20, p. 40. 1971–1978: *1978 report, forest planting, seeding, and silvical treatments in the United States*, USDA Forest Service (Washington: USGPO, 1979).

Area burned by wildfire: *Historical statistics of the United States, colonial times to 1970*, U.S. Bureau of the Census (Washington: USGPO, 1975), p. 537. *1977 wildfire statistics*, USDA Forest Service (Washington: USGPO, 1979), table 2, p. 14, and previous annual issues.

Spruce budworm defoliation: *Forest insect and disease conditions in the United States, 1977*, USDA Forest Service (Washington: USGPO, 1978), figs. 1, a, pp. 39, 57.

Data on seeding include forest plantings, windbarrier plantings, and direct seedings in fiscal years.

7-17
Recreational use of the National Forests, 1965-1977

USDA Forest Service, Recreation Information Management System, unpublished data.

Mechanized recreation travel includes: automobiles, scooters and motorcycles, ice and snowcraft (primarily snowmobiles), specialized land craft (primarily all-terrain vehicles), train and bus touring, aircraft use, aerial trams and lifts, non-motorized aircraft, and bicycles.

7-18
Recreational use of the National Forests, by activity, 1977

Statistical abstract of the United States: 1978, U.S. Bureau of the Census (Washington: USGPO, 1978), table 396, p. 243.

Resort and residence use includes day and overnight visits.

Nature study includes viewing scenery, sports, and entertainment.

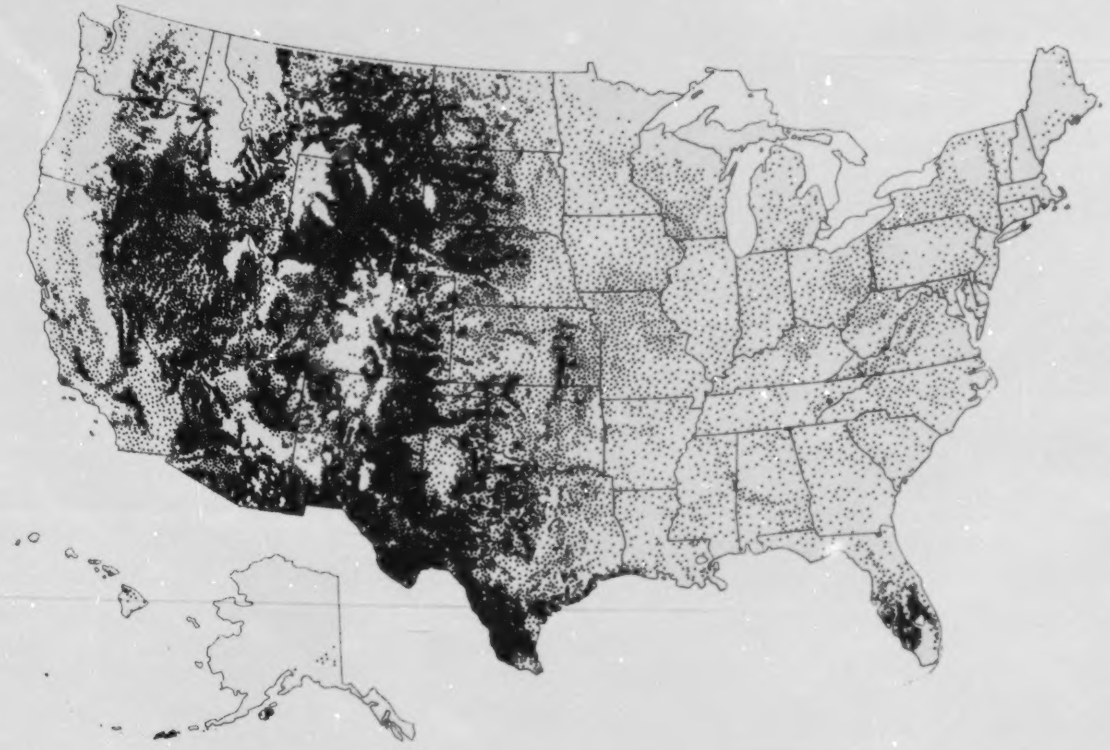
Picnicking includes games and team sports.

Rangeland

Rangelands cover more than a third of the land—the vast prairies of the Midwest, the semiarid plains and deserts of the Southwest, and large areas of Alaskan tundra.

Little effort was made to manage and protect this grazing resource until the late 1930s. For years, the quality of the land suffered from chronic overgrazing, lack of soil conservation, and generally poor range management. Federal laws enacted in the past 20 years direct the Forest Service and the Bureau of Land Management to manage Federal rangelands for multiple uses. The uses include grazing for domestic and wild animals, habitat protection for endangered species, recreation, mining, and aesthetics.

7-19
Rangeland



Each dot represents 25,000 acres

Rangeland occupied 820 million acres in 1976, a figure that has changed little in the past 25 years. The largest areas are in the West and Southwest.

Rangeland refers to all land on which the vegetation is predominantly grasses, grasslike plants, or shrubs. It includes land with less than 10% in forest trees of any kind and excludes improved pasture land.

In 1977, most of this land was actively grazed by domestic animals sometime during the year. The rest was either too poor to support grazing or was too isolated.

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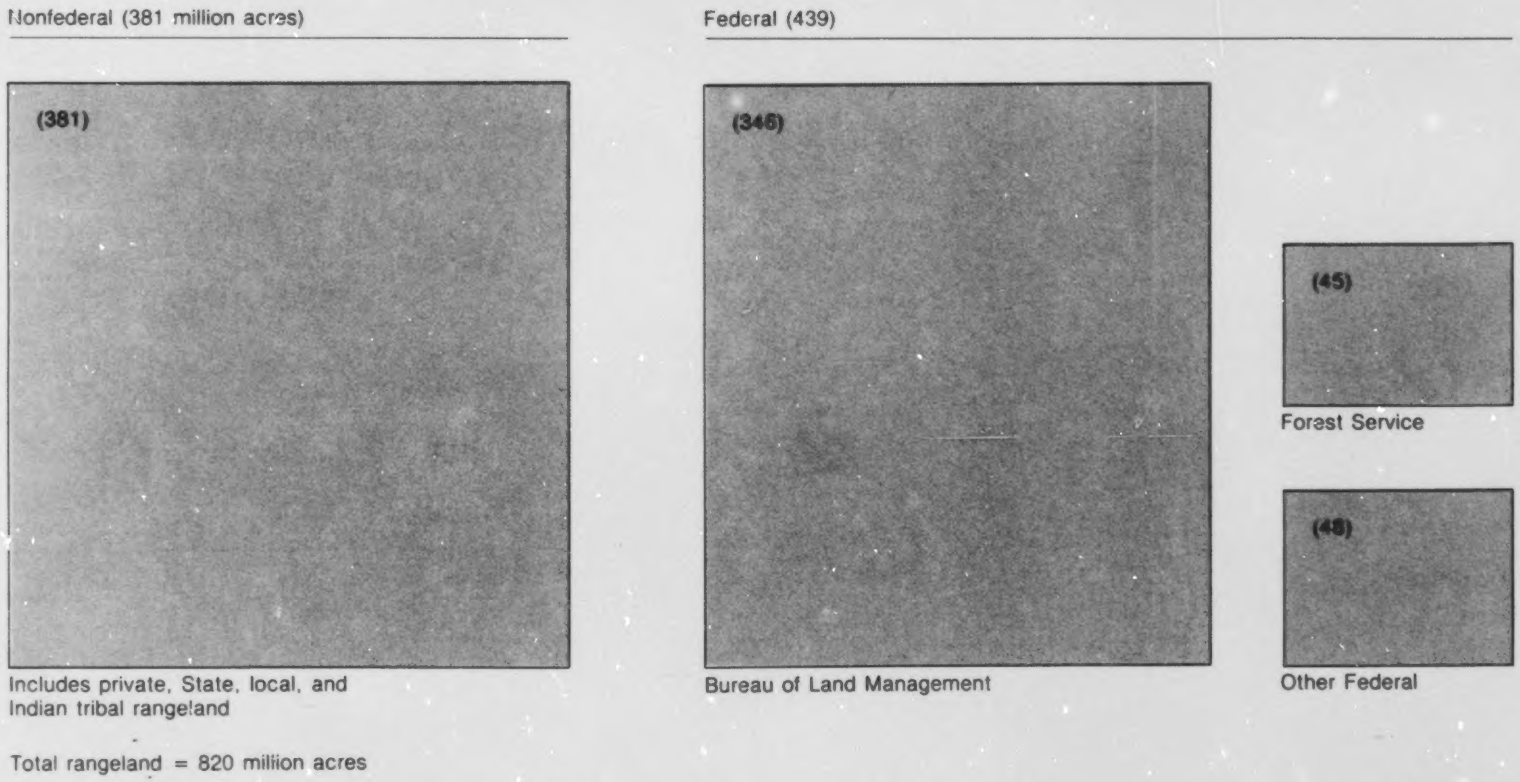
7-20

Ownership of rangeland, 1977

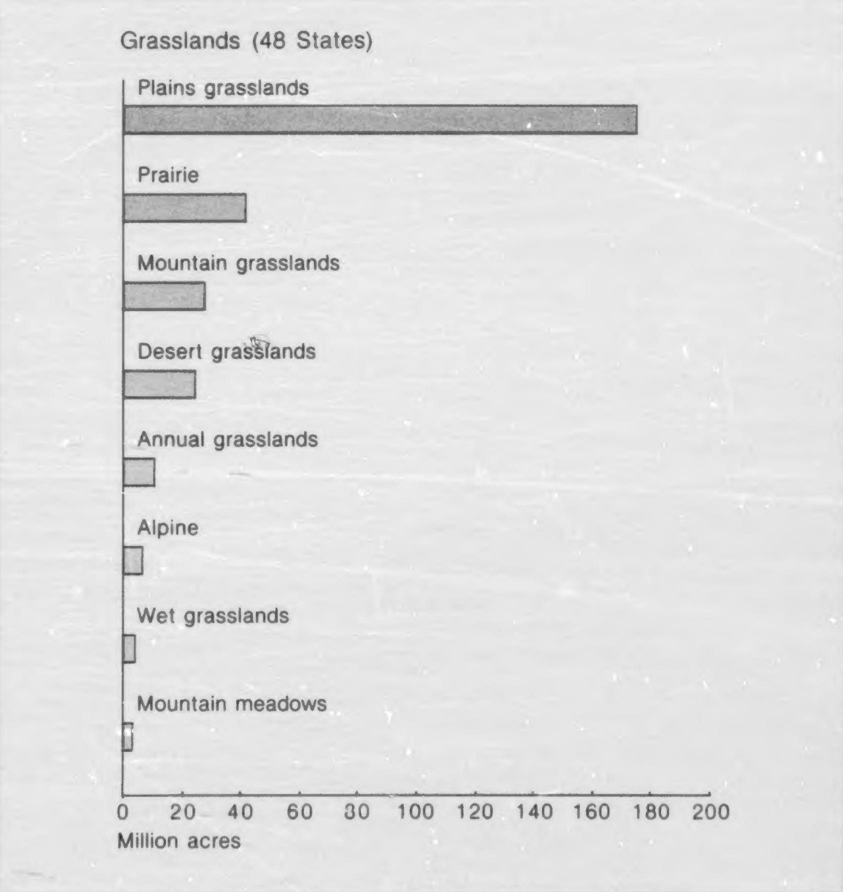


The Federal Government owns more than half of all rangelands and leases more than 17 million acres to private ranchers for grazing.

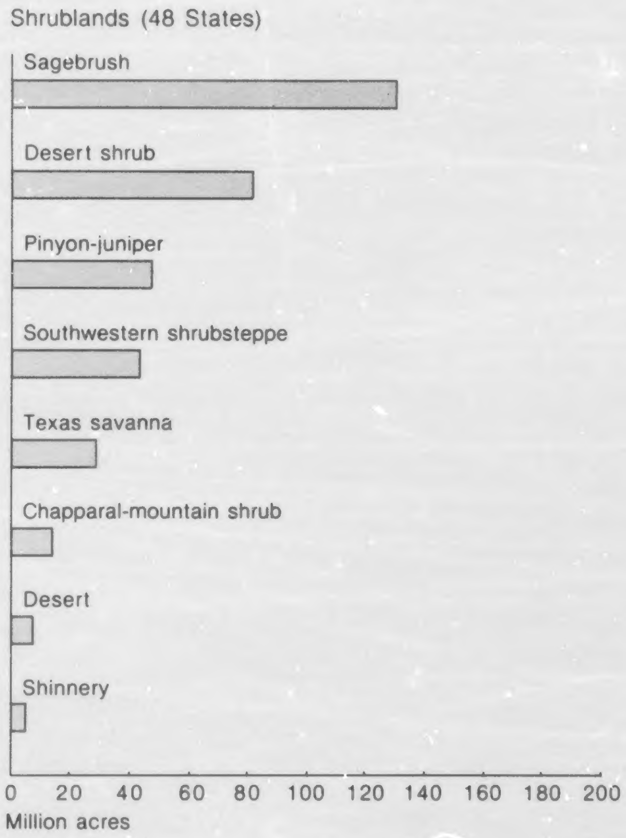
7-21

Rangeland, by ecosystem, 1976

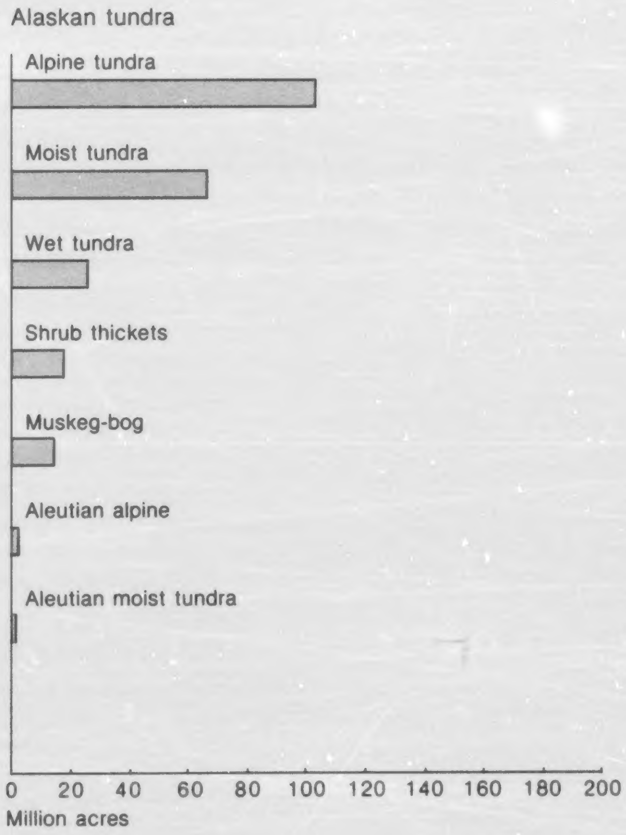
Rangelands are of three major types or ecosystems: grasslands, shrublands, and Alaskan tundra.



The plains grasslands are the most extensive. The largest are in Montana, Wyoming, the Dakotas, Colorado, and Texas, where they support the range cattle and sheep industries. The mountain meadows and alpine grasslands provide a variety of recreational activities, including wilderness camping. Energy resource development, particularly coal and oil shale, and copper, sand, gravel and phosphate mining often take place on rangelands.

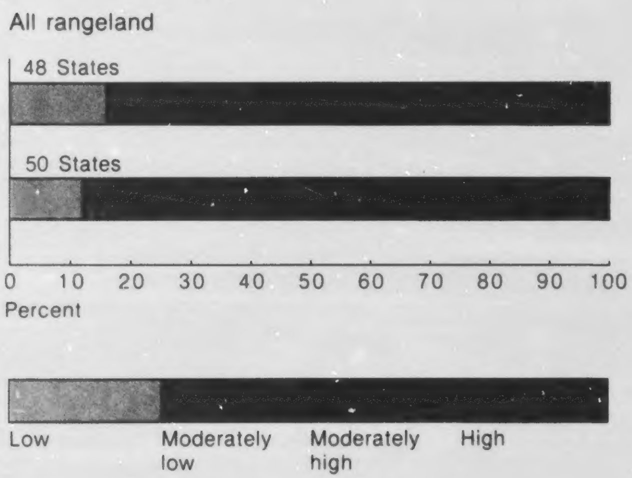


The largest shrublands are in Nevada, Utah, Arizona, and Texas. Some of the lands are used for livestock grazing, but most are left to wildlife.



The Alaskan rangeland is largely tundra—a treeless plain, characteristic of arctic and subarctic regions. Much of this land contains permanently frozen subsoil, but it can support some vegetation such as lichens—the principal food of the caribou.

7-22
Quality of rangeland, by ecosystem, 1976



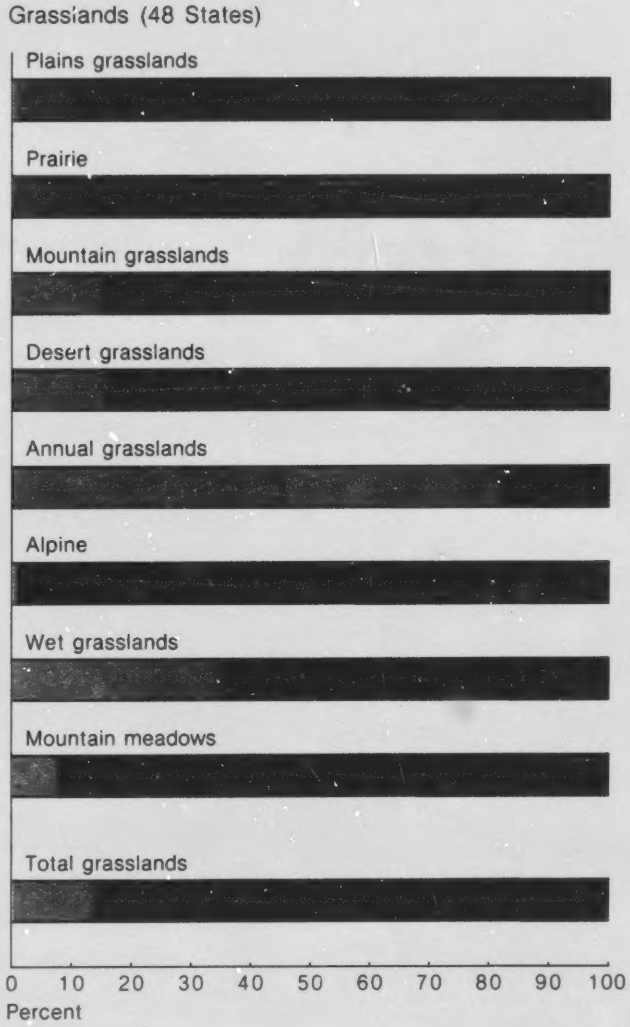
The condition of the rangeland depends on many factors—the intensity of grazing by domestic and wild animals, off-road vehicle use and other disturbances of the land, concentrated use by individuals, use of herbicides, harvesting of timber, wildfires, damage by insects and disease, even major weather changes. All modify the vegetation and soils of rangelands.

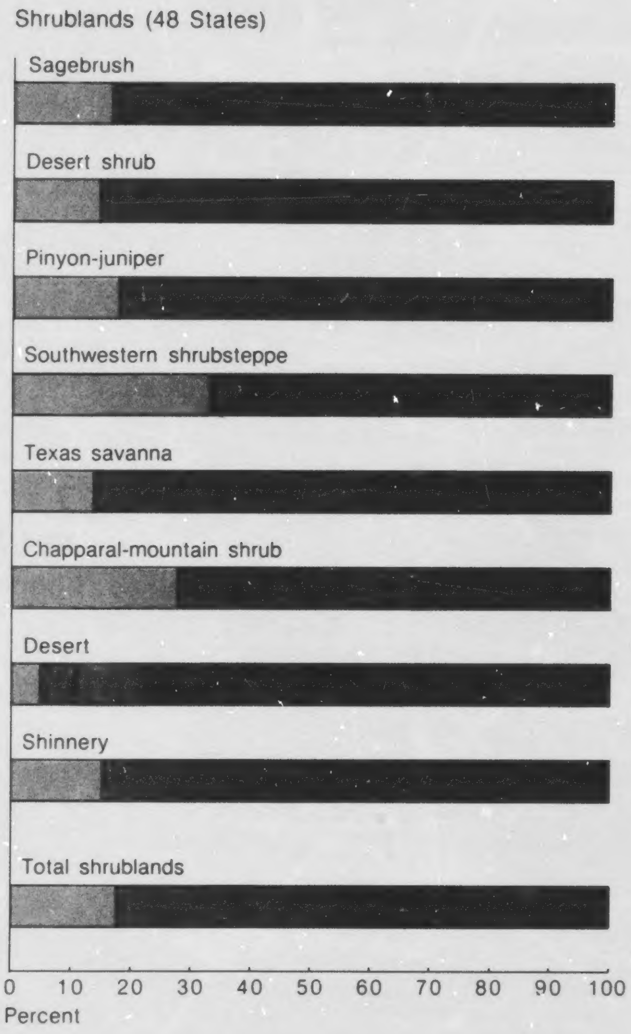
One measure of the condition of rangelands is the extent to which the ecological growth potential of a site has been met. High quality range is land on which vegetation and soils meet 60% of the site potential; low quality range is land on which vegetation and soils meet 20% or less of its potential. Without intense human use, almost all rangeland would fall into the high or moderately high category.

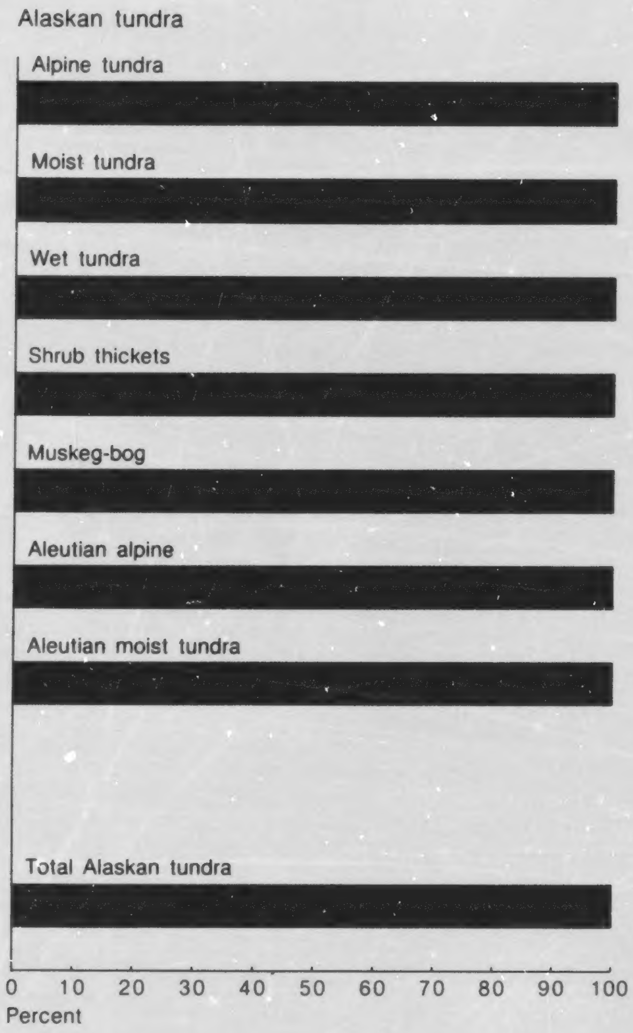
Less than half the grasslands are of high or moderately high quality. About 40 million acres are low quality, mainly because of overgrazing.

Overall, about 45% of shrublands are of high or moderately high quality. The Southwestern shrubsteppe is in the least satisfactory condition.

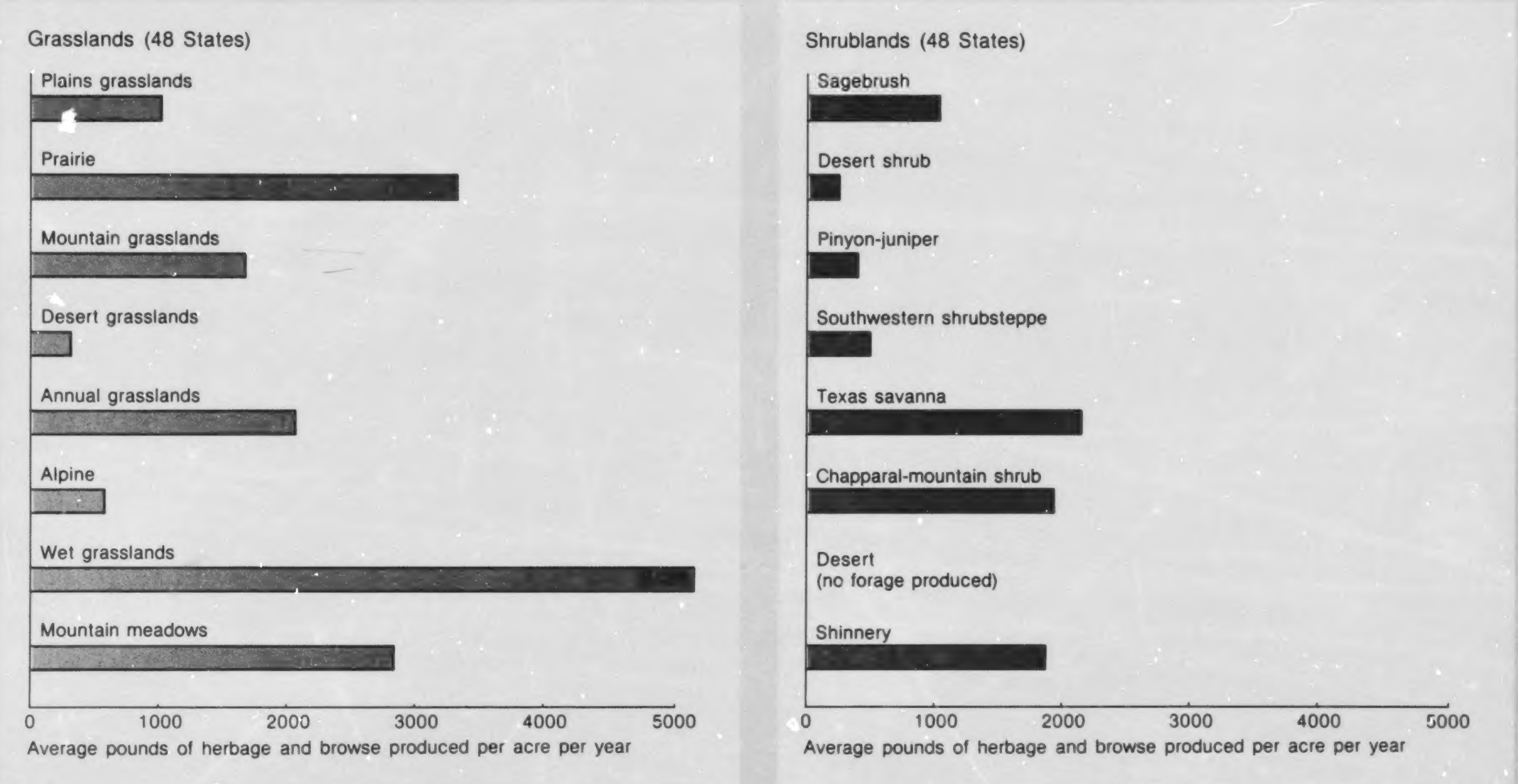
Nearly all Alaskan rangelands are of high quality.




Shrublands (48 States)
Sagebrush
Desert shrub
Pinyon-juniper
Southwestern shrubsteppe
Texas savanna
Chapparal-mountain shrub
Desert
Shinnery
Total shrublands
0
10
20
30
40
50
60
70
80
90
100
Percent


Alaskan tundra
Alpine tundra
Moist tundra
Wet tundra
Shrub thickets
Muskeg-bog
Aleutian alpine
Aleutian moist tundra
Total Alaskan tundra
0
10
20
30
40
50
60
70
80
90
100
Percent

7-23
Productivity of rangeland, by ecosystem, 1976



The productivity of rangelands varies widely by location and ecosystem. The southern cordgrass and Everglades wet grasslands average from 4,000 to 8,000 pounds of herbage and browse annually. The best sites can produce 10,000 pounds or more per year. The large grasslands and prairies of the Great Plains produce 1,000 to 3,000 pounds of herbage and browse each year.

At the other extreme is the desert shrub of western Texas which produces only 200 to 400 pounds per year. The Alaskan ecosystems also have generally low productivity, less than 1,000 pounds per acre per year.

7-19
Rangeland

The national atlas of the United States of America, U.S. Geological Survey (Washington, D.C., 1970), p. 160.

Map shows rangeland area for 1959 and includes cropland used only for pasture, pastured woodland, other pasture land in farms, and grazing land not in farms.

Excluded are two ecosystems which can be considered either forest land or rangeland: pinyon-juniper (47 million acres) and chapparal-mountain shrub (14 million acres). With these two ecosystems, total rangeland is 881 million acres in 1976.

7-20
Ownership of rangeland, 1977

Review draft of "An assessment of the forest and rangeland situation in the United States," USDA Forest Service (Washington, D.C., 1979), p. 242.

All data are preliminary.

Excluded are the pinyon-juniper and chapparal-mountain shrub ecosystems.

7-21
Rangeland, by ecosystem, 1976

See 7-20, p. 29.

All data are preliminary.

7-22
Quality of rangeland, by ecosystem, 1976

See 7-20, p. 242.

All data are preliminary.

Excluded are 1 million acres in Hawaii which are of varying quality.

High indicates that vegetation and soils deviate from site potential by less than 40%. Moderately high, by 40 to 59%. Moderately low, by 60 to 79%. Low, by 80% or more from potential.

7-23
Productivity of rangeland, by ecosystem, 1976

See 7-20, p. 35.

All data are preliminary.

Excludes Alaska and Hawaii.

Chapter 8

Wildlife

Over hundreds, thousands, even millions of years, plant and animal species grow and decline in number and extent of range. They adapt genetically and sometimes behaviorally in order to reproduce and to survive. When a population cannot adapt to changing environmental conditions, it becomes extinct.

Fluctuations in wild animal and plant populations, once caused primarily by changes in climate and interactions with other species, are influenced increasingly often by human activity. In fact, the continued existence of millions of wild species depends on human willingness to provide for their conservation.

To mitigate these threats, Federal, State, and local governments have established a variety of programs which have helped to conserve game species, species subject to commercial harvest, and some species known to be threatened or endangered. More recently, government, conservation organizations, and concerned individuals are now promoting conservation of nongame animals and wild plants as well.

The greatest threat to wildlife is now from habitat modification. Construction, urbanization, other development, agriculture, and intensive management for one or a few species contribute to the decline of available habitat. Other threats are pollution, displacement by exotic species, and excessive harvest.

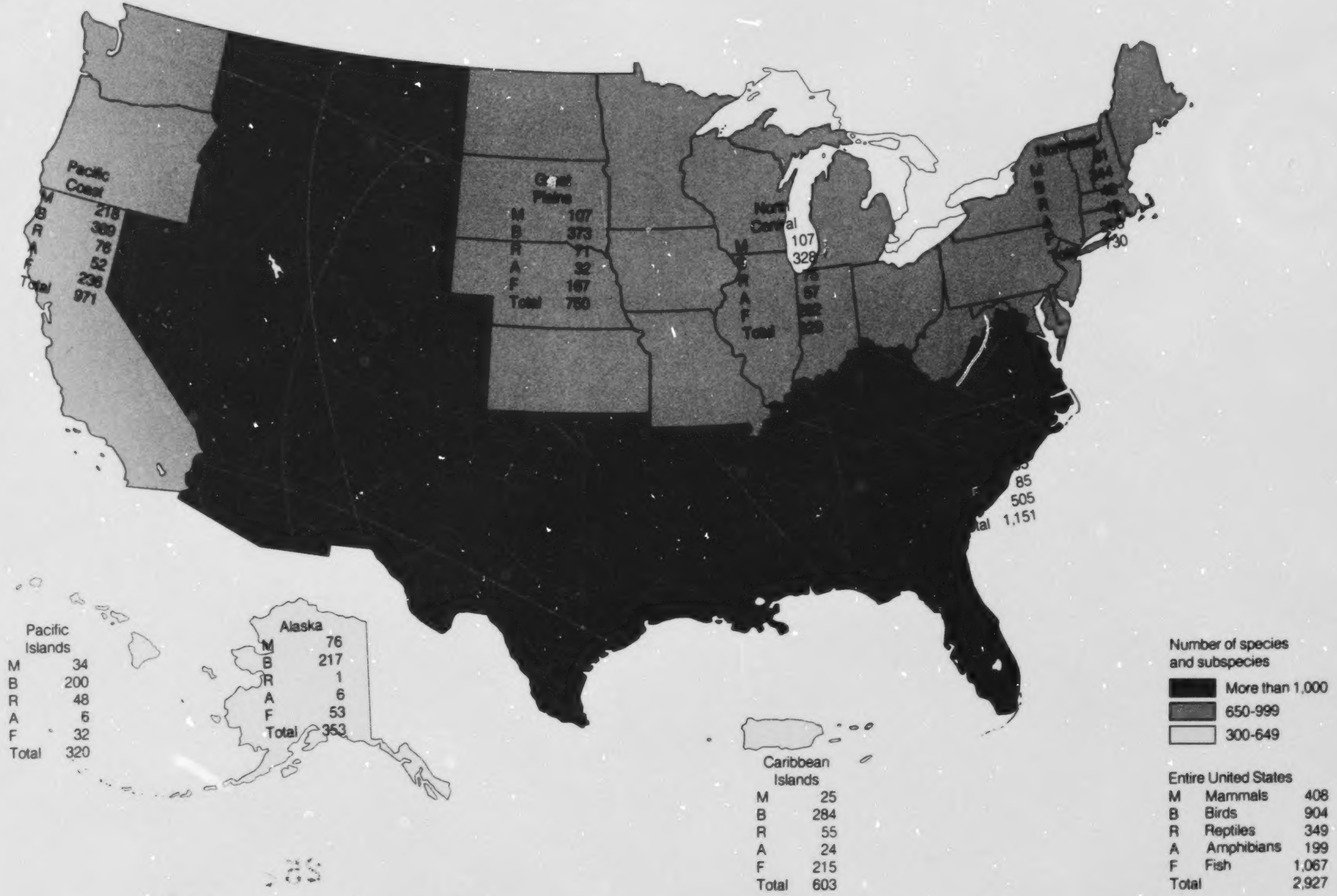
8-1

Distribution of vertebrate species and major subspecies, by region, 1970s

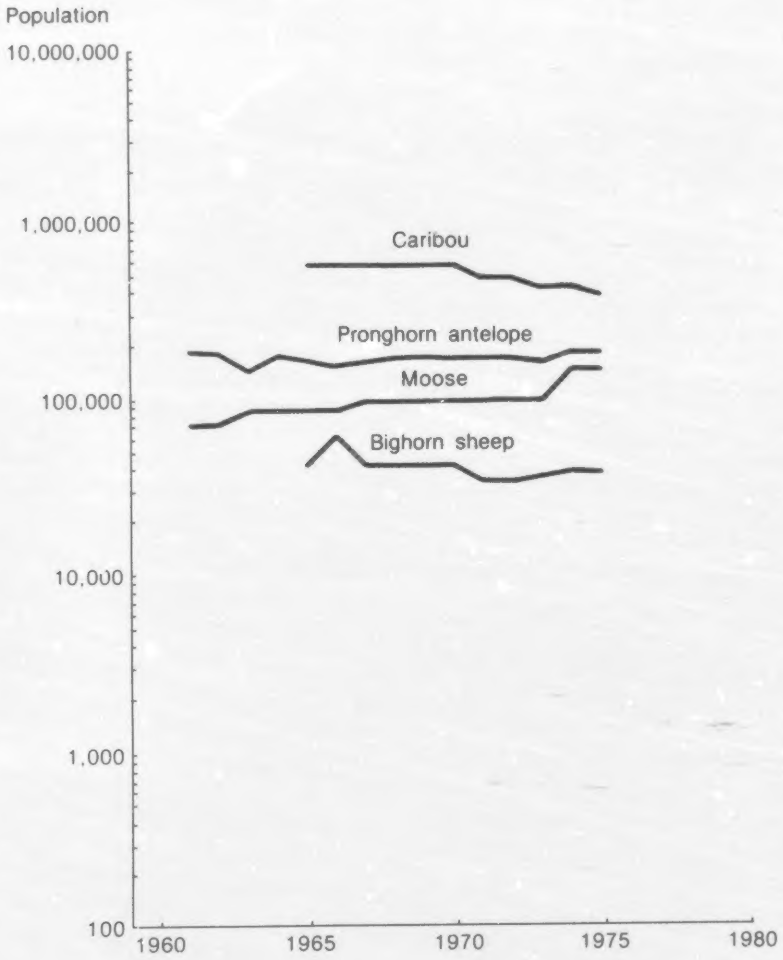
The lands and waters of the United States support 2,900 species of vertebrates—430 mammals, 1,000 birds, 300 reptiles, 175 amphibians, and more than 1,000 fishes. There are an additional tens of thousands of invertebrate and plant species. A few animals and plants are found in many types of habitat throughout the Nation, but most require specific habitats, some of which are quite small.

The largest numbers of reptile, amphibian, and bird species are in the South. The largest number of fish species are in the Southeast, in both fresh and salt water, and the most mammal species are in the Rocky Mountains, the Great Plains, and the Pacific Coast.

About 766 million acres of Federal, State, and local public lands provide some degree of protected habitat for wildlife. Most are in the West. Some are managed to provide food and natural shelter for selected species. Others are simply wilderness. In addition to these public lands, millions of acres of private lands, largely in the East, provide suitable habitat for wildlife.


Pacific Coast
M 218
B 389
R 76
A 52
F 236
Total 971
Great Plains
M 107
B 373
R 71
A 32
F 167
Total 750
North Central
M 107
B 328
R 75
A 57
F 262
Total 829
Northeast
M
B
R
A
F
Total 730
85
505
Total 1,151
Pacific Islands
M 34
B 200
R 48
A 6
F 32
Total 320
Alaska
M 76
B 217
R 1
A 6
F 53
Total 353
Caribbean Islands
M 25
B 284
R 55
A 24
F 215
Total 603
Number of species and subspecies
More than 1,000
650-999
300-649
Entire United States
M Mammals 408
B Birds 904
R Reptiles 349
A Amphibians 199
F Fish 1,067
Total 2,927

8-2
Selected large mammal populations on Bureau of Land Management lands, 1961–1975



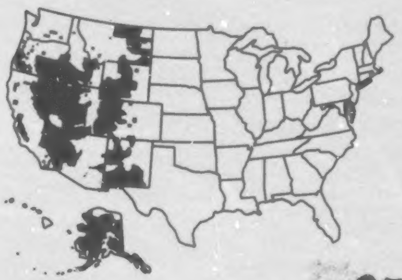
For many mammals, particularly large ones, habitat modification or destruction and excessive killing have reduced population size, and some species are in danger of becoming extinct. Because most Federal and State conservation efforts focus on mammals of commercial or sports value, particularly the large herbivores, these are the species whose habits and numbers are best known and which have been most efficiently conserved.

Large native land mammals include the peccary *(Tayassu tajacu)*, pronghorn antelope *(Antilocapra americana)*, bighorn sheep *(Ovis canadensis)*, Dall sheep *(Ovis dalli)*, mountain goats *(Oreamnos americanus)*, caribou *(Rangifer tarandus)*, whitetail *(Odocoileus virginianus)*, blacktail *(Odocoileus hemionus columbianus)*, and mule deer *(Odocoileus hemionus)*, elk *(Cervus canadensis, Carvus nannodes)*, moose *(Alces alces)*, bison *(Bison bison)*, black bears *(Ursus americanus)*, grizzly bears *(Ursus arctos)*, mountain lions *(Felis concolor)*, and gray wolves *(Canis lupus)*. Most of these species require large areas to maintain viable populations in the wild.

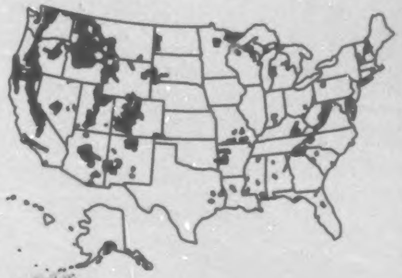
Deer, the most prevalent of the large mammals, are found in forests and on rangelands in most of the country. The whitetail population, for example, has grown as cutover forests and abandoned farmlands in the East have grown back. Deer, numbering in the millions, are believed to be as abundant today as they were prior to European settlement.

Elk populations are estimated at 25% of presettlement totals, and pronghorn antelope at 2% to 3%. The bighorn sheep and bison are both estimated at less than 1% of early levels.

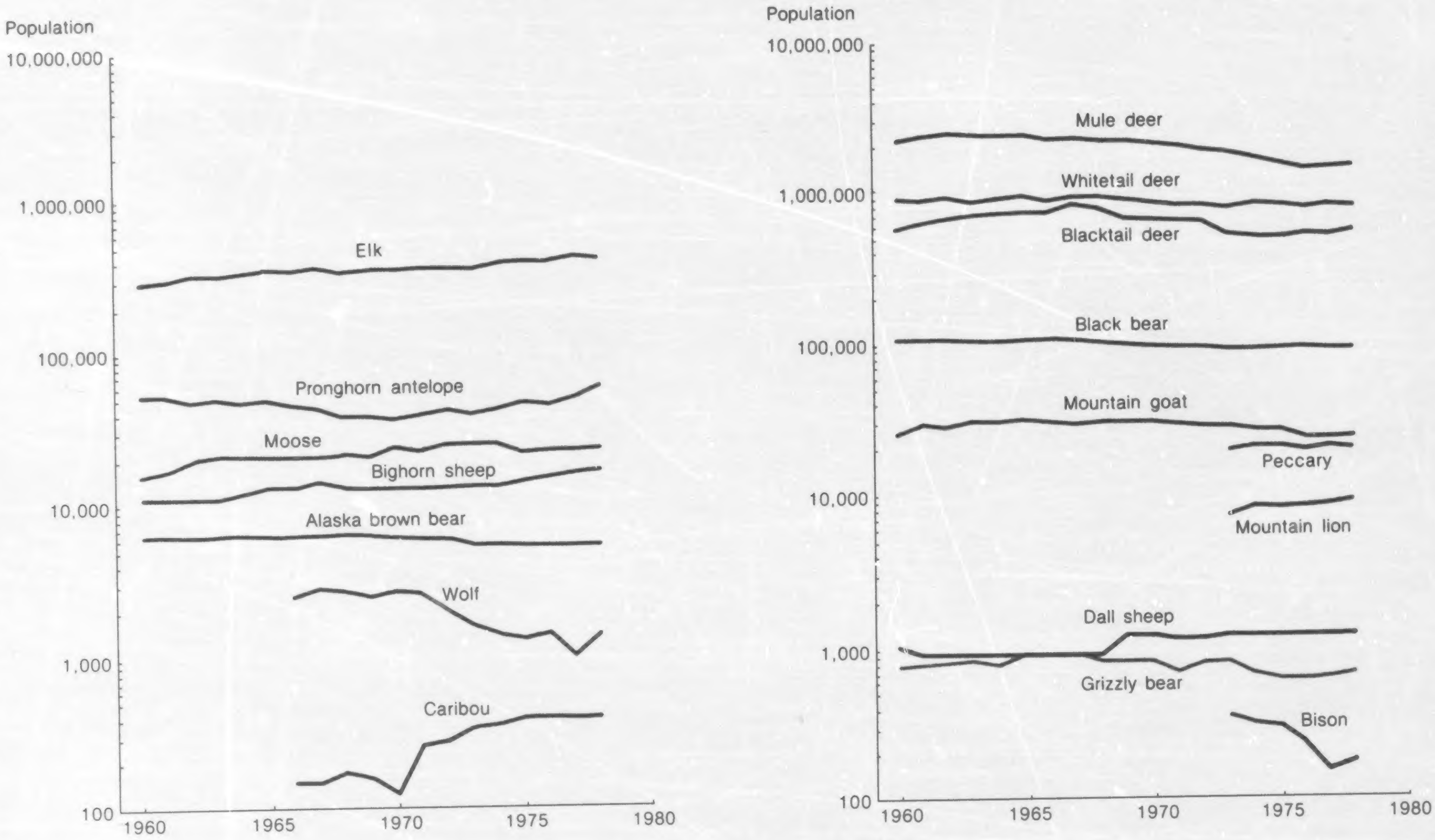
Bureau of Land Management lands



National Forests and National Grasslands



8-3
Selected large mammal populations in National Forests and National Grasslands, 1960–1978

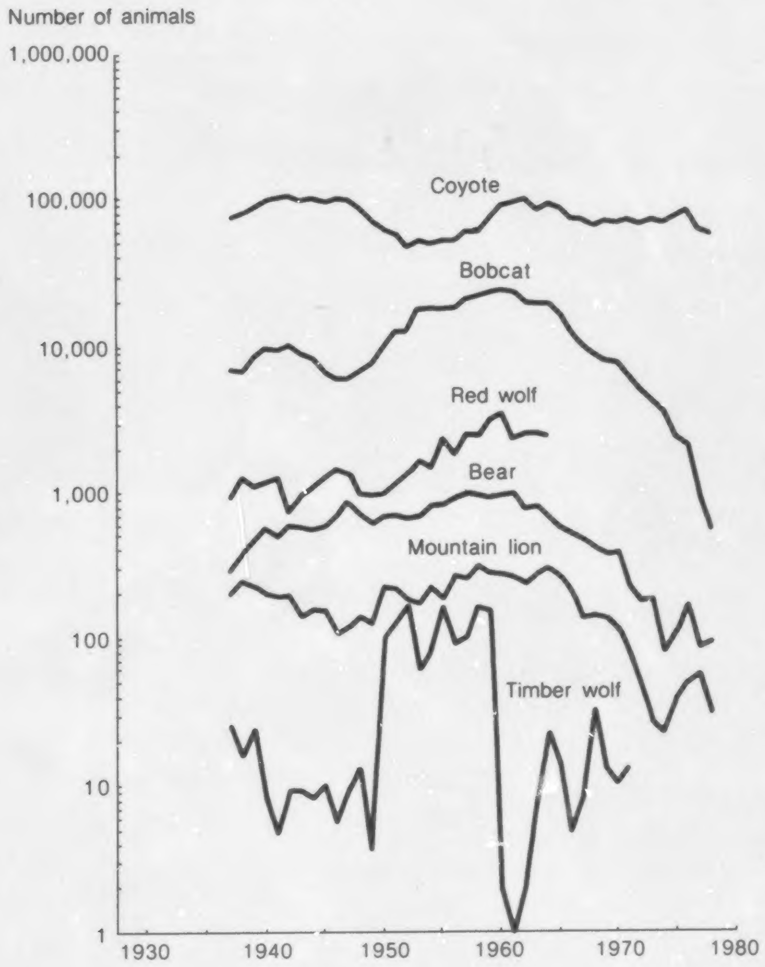


257

258

8-4
Animals removed or killed by Federal predator control activities, 1937–1978

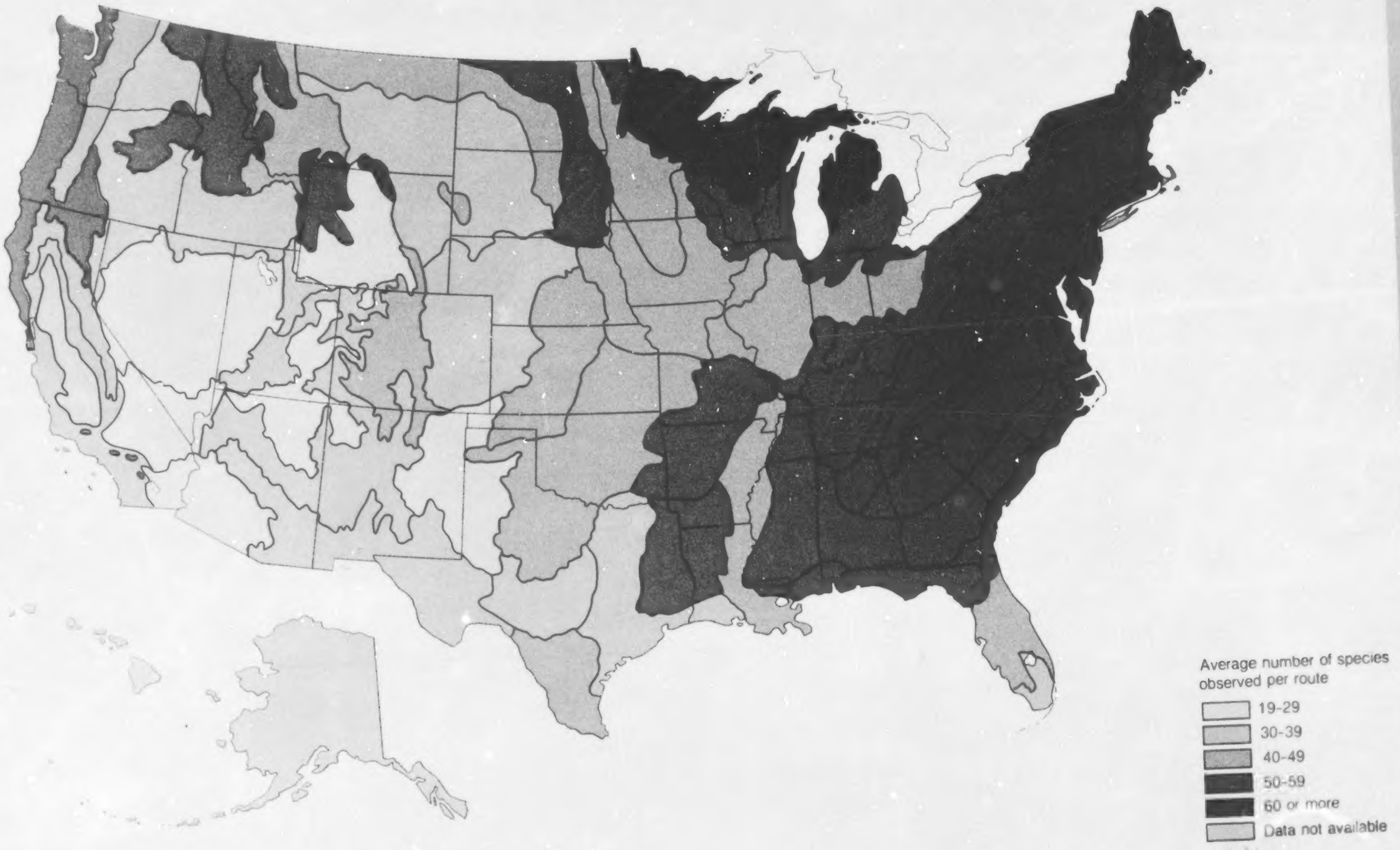
Hunting, trapping, and poisoning have been the traditional response to animals considered predators. Such killing has decreased substantially since the mid-1960s, when Federal predator control programs were curtailed.



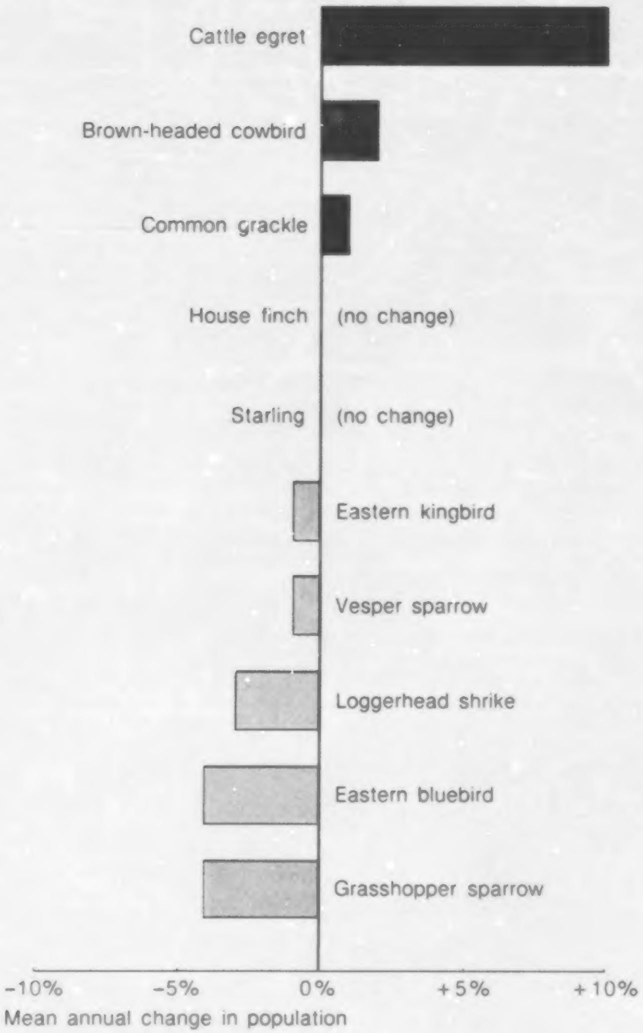
8-5
Bird species observed, 1968–1977

Birds are the most visible of the vertebrates, and there are more than 900 known species that vary in form and habit. Some have feeding habits as specialized as the Everglades kite *(Rosthrhamus sociabilis plumbeus)*, which eats only a single species of snail; the blue jay *(Cyanecitta cristata)*, on the other hand, is a generalized feeder. Birds live almost everywhere—from remote forests, mountain tops, and far out at sea to central cities. There is also great variety in the areas over which they carry out their activities. The home range of Belding's savannah sparrow *(Passerculus sandwichensis beldingi)* covers only about 6,500 square feet (600 square meters); the golden eagle *(Aquila chrysaetos)* has a range of 36 square miles (93,000,000 square meters).

On a given day in the nesting season, the largest number of bird species has been observed in the Great Lakes Pine Belt and the spruce-hardwood forests of the Northeast; the fewest have been in the deserts of the Great Basin. During the 10 years of the annual Breeding Bird Survey, the average number of species observed in an area changed very little, but there were many changes in the number of individuals observed.


Average number of species observed per route
19-29
30-39
40-49
50-59
60 or more
Data not available

8-6
Selected bird species populations, 1966–1977



Some species are becoming more widespread; others are declining in number and range. In some areas, exotic birds and birds that can thrive in a disturbed habitat are becoming more common at the expense of native birds.

A native of Africa, now established in the eastern States, the cattle egret *(Bubulcus ibis)* is rapidly spreading west. There is little competition for its primary habitat, cattle pastures.

Mechanical harvesting increases the supply of grain, thus reducing winter mortality of the brown-headed cowbird *(Molothrus ater)* and the common grackle *(Quiscalus quiscula)*.

The house finch *(Carpodacus mexicanus)* is native to the West. Released in New York, it spread through the eastern States. It has adapted well to suburban habitats.

After rapidly moving west, the starling *(Sturnus vulgaris)* is now common throughout the United States and Canada. It is slowly spreading north to Alaska.

Loss of farm hedgerows has affected the population of the eastern kingbird *(Tyrannus tyrannus)*.

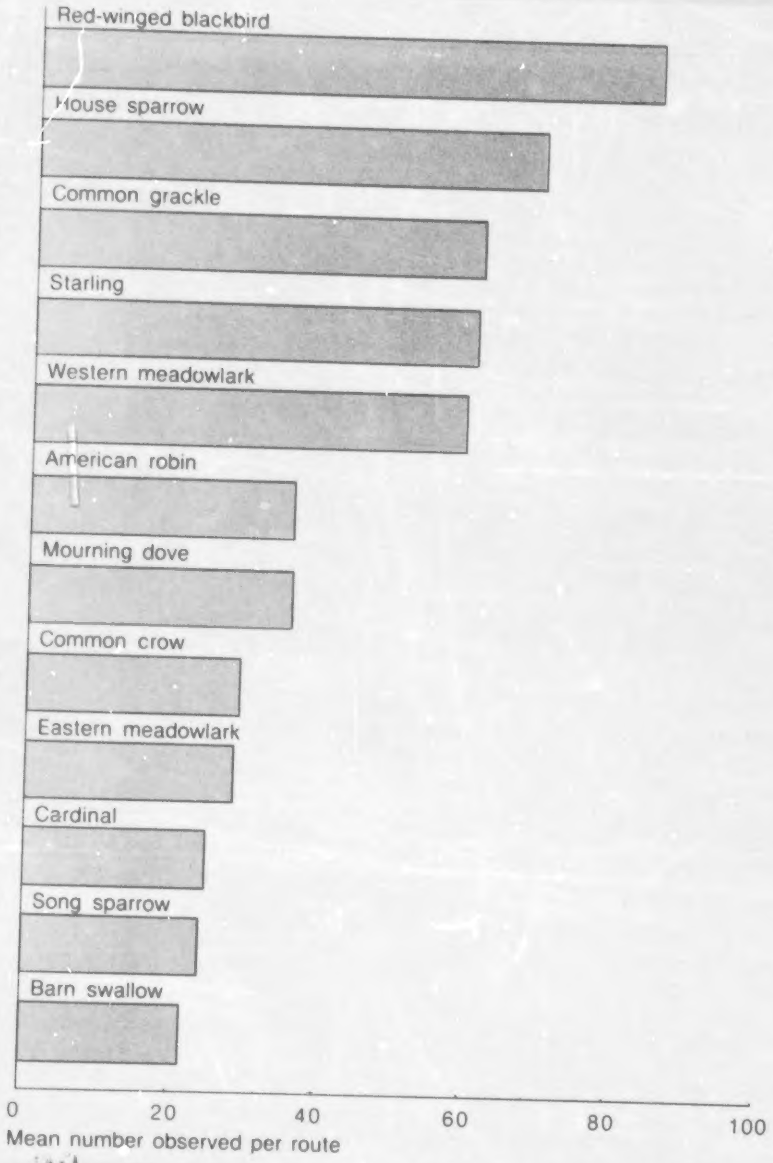
Conversion of farmlands to residential areas has influenced the populations of the vesper sparrow *(Pooecetes gramineus)* and the loggerhead shrike *(Lanius ludovicianus)*.

The eastern bluebird *(Sialia sialis)* population has decreased as a result of abnormally cold winters and competition for nesting sites with starlings and house sparrows.

The grasshopper sparrow *(Ammodramus savannarum)* population has declined in part as a result of the conversion of farmlands to residential areas.

8-7

Most frequently observed breeding bird species, 1977

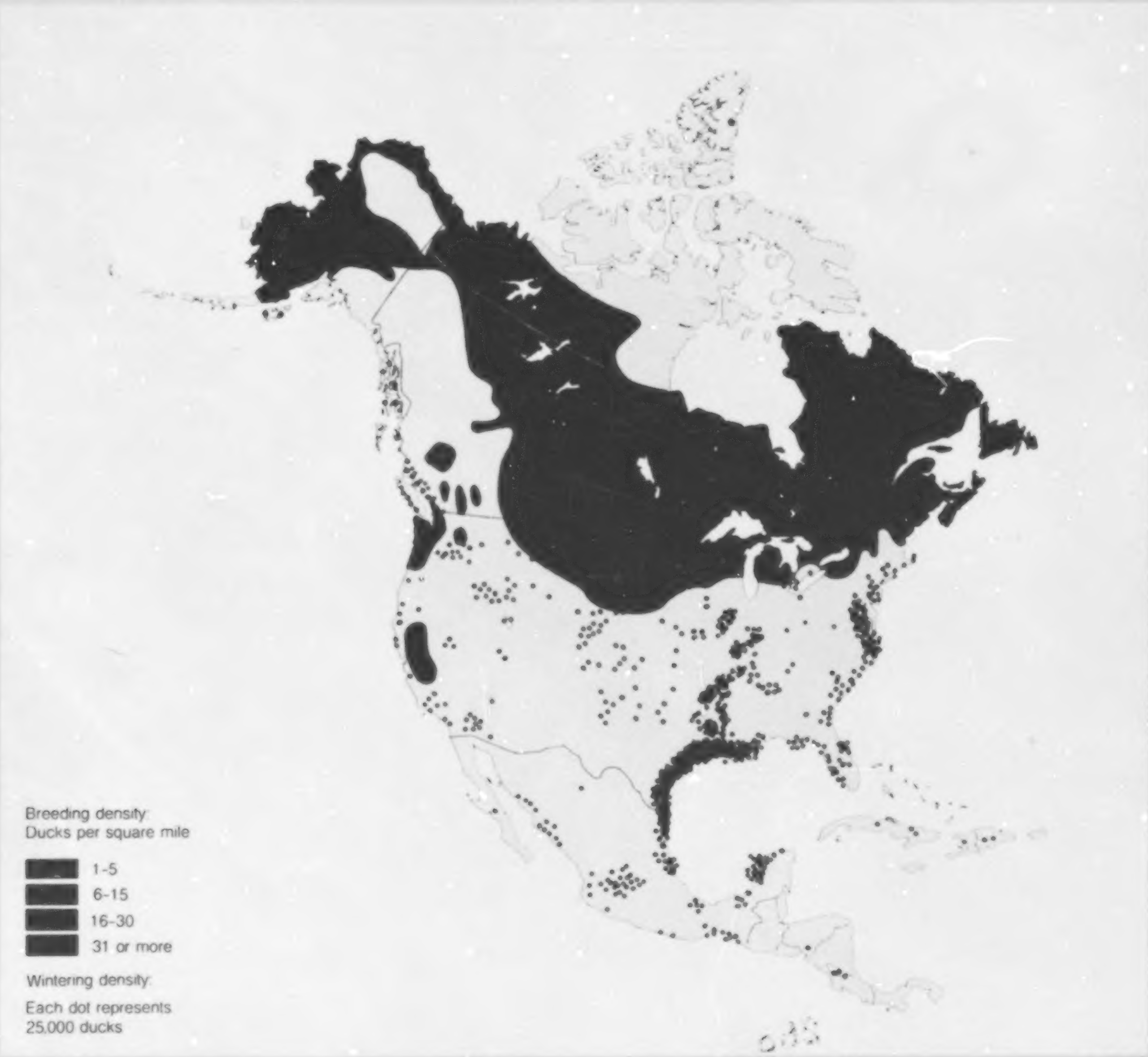


The 12 most commonly observed bird species breeding in the United States are: the red-winged blackbird *(Agelaius phoeniceus)*, house sparrow *(Passer domesticus)*, common grackle *(Quiscalus quiscula)*, starling *(Sturnus vulgaris)*, western meadowlark *(Sturnella neglecta)*, American robin *(Turdus migratorius)*, mourning dove *(Zenaida macroura)*, common crow *(Corvus brachyrhynchos)*, eastern meadowlark *(Sturnella magna)*, cardinal *(Cardinalis cardinalis)*, song sparrow *(Melospiza melodia)*, and barn swallow *(Hirundo rustica)*.

8-8

Distribution of North American breeding and wintering ducks, 1970s

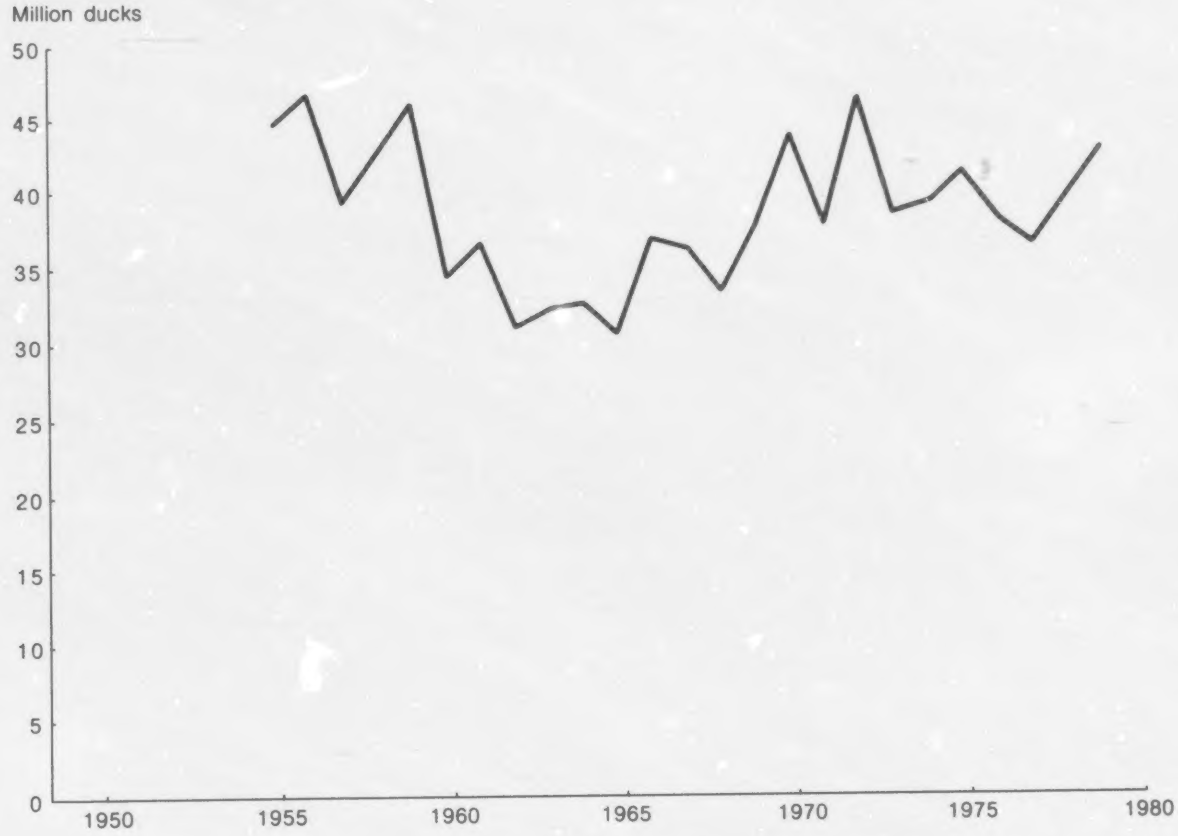
Migratory waterfowl travel from Alaska and northern Canada to South America. Most of them breed in the North and fly south for the winter—a pattern that requires wetland habitats for breeding and for wintering, with food and shelter along the way. The birds generally follow one of four primary north-south migration routes or flyways—along the Pacific coast, over the Central States, along the Mississippi River, or along the Atlantic coast.


Breeding density:
Ducks per square mile
1-5
6-15
16-30
31 or more
Wintering density:
Each dot represents 25,000 ducks

8-9

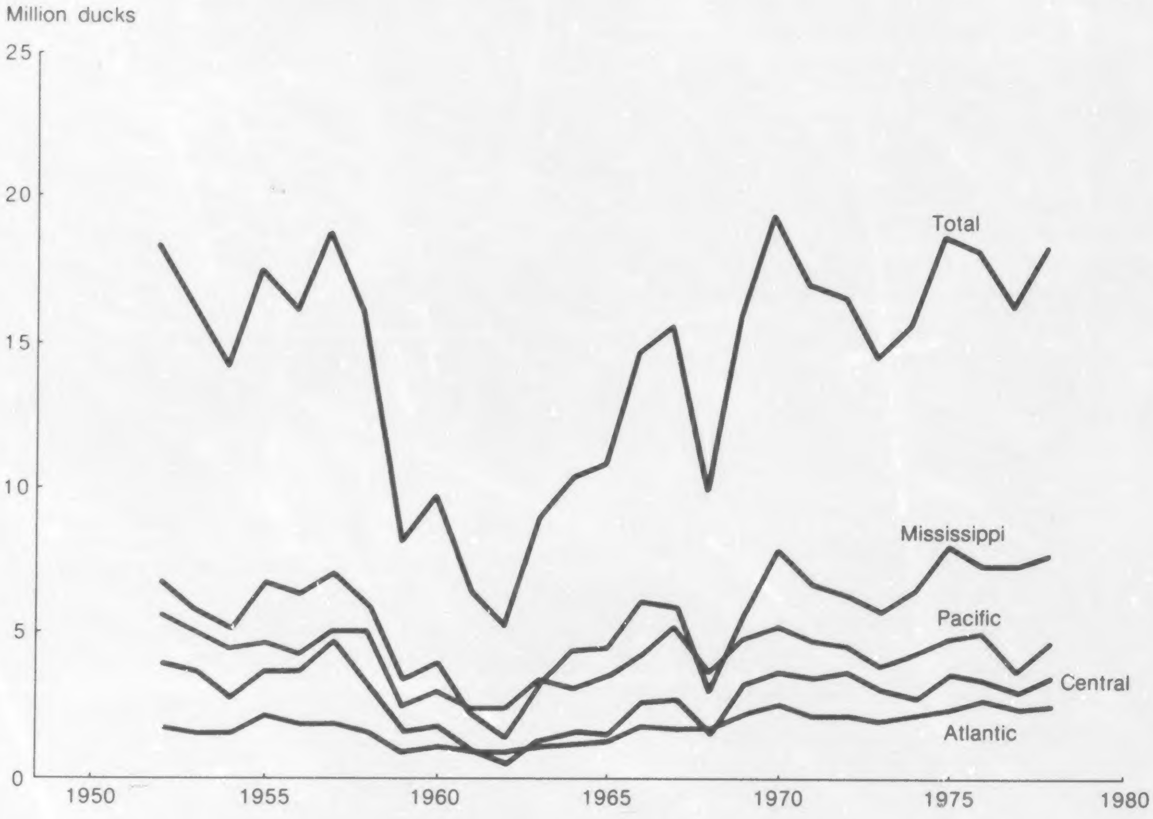
Duck breeding populations in North America, 1955–1979

Duck and goose populations, ranging in recent years from 30 million to more than 50 million breeding birds, fluctuate with annual weather conditions on the breeding grounds. For such species as arctic-nesting geese, the onset of breeding is influenced by the extent and duration of snow cover. Nesting that is delayed until June generally results in fewer young in the fall migration south. Production of young in the major breeding areas (North and South Dakota, Alberta, Saskatchewan, and Manitoba) is generally good during years of normal or above average precipitation.



8-10

Duck harvest, by flyway, 1952–1978



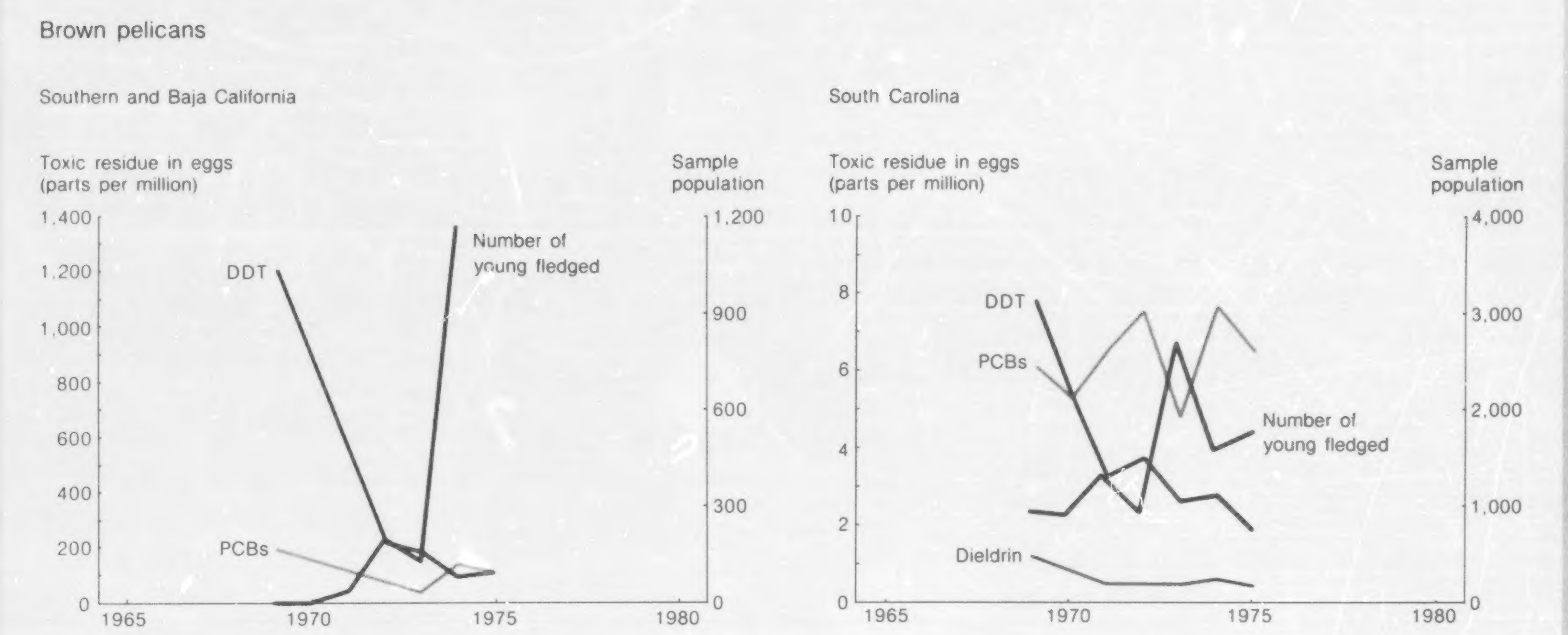
The harvest of ducks has fluctuated between 5 and 19 million in the past 26 years. In general, the larger the duck population, the larger the harvest. Roughly 15% of the fall duck population is killed each year by hunters.

Excessive hunting has historically led to depleted populations of migratory waterfowl, but a more important long-term influence is the loss of natural habitat, particularly wetlands.

To protect wetland breeding areas, the Federal Government manages 1.6 million acres in Minnesota, Montana, Nebraska, North Dakota, South Dakota, and Wisconsin in addition to wintering and feeding lands along the major flyways. Most breeding and wintering activities take place on private property, particularly farmland, which is often under consideration for drainage and future cultivation. The most threatened wetlands used by migratory waterfowl are in the Mississippi Valley.

8-11

Brown pelican populations and toxic residues in eggs, 1969–1976



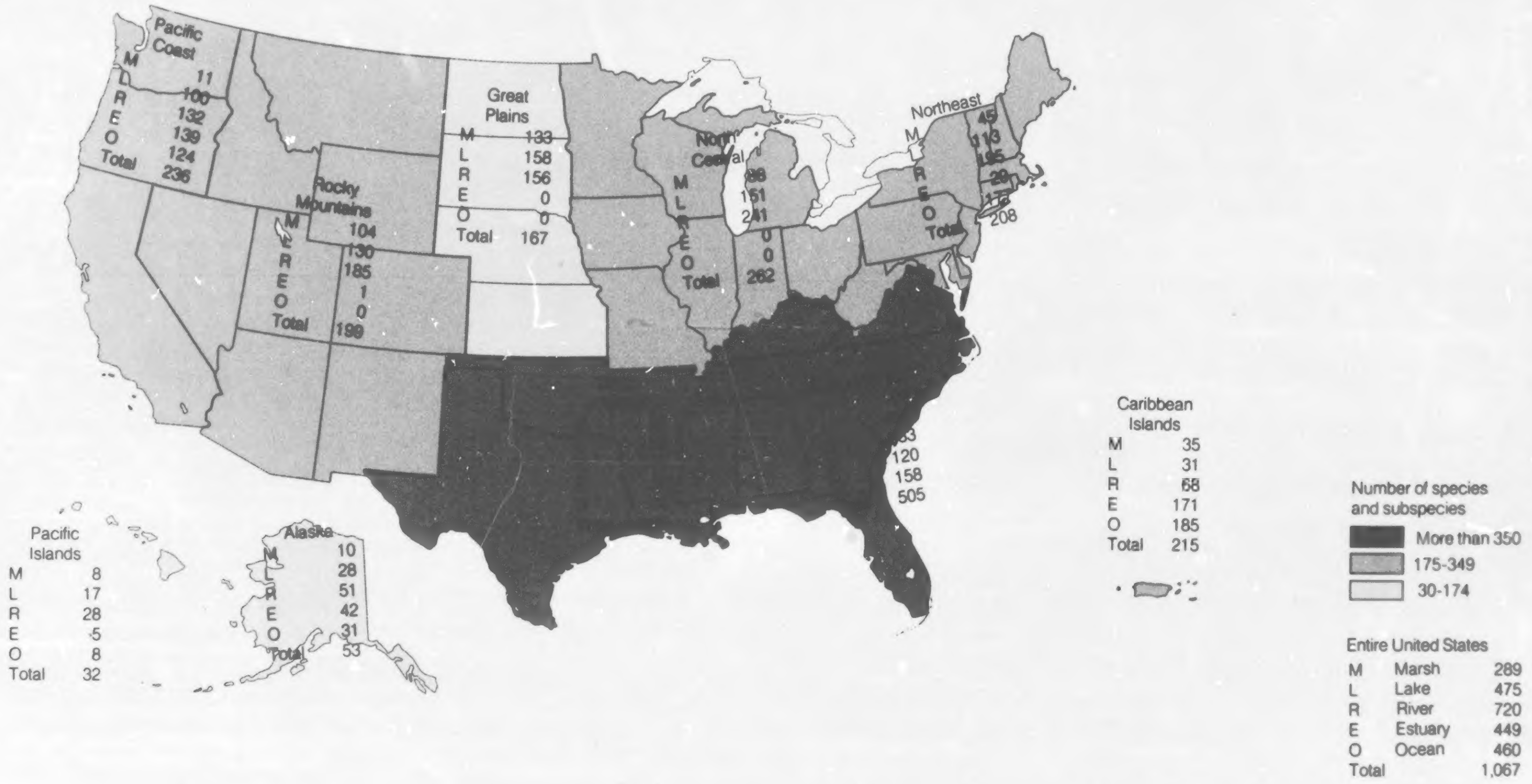
In addition to loss of habitat, toxic substances in the environment are a threat to birds—particularly the large predatory species. DDT, its derivatives, and other chlorinated hydrocarbons are examples of chemical contaminants that accumulate in animal tissue. These compounds interfere with calcium metabolism, causing eggshells to be thin and making the eggs too fragile to survive hatching.

After DDT was banned for most uses in 1972, levels in the eggs of brown pelicans *(Pelecanus occidentalis)* decreased significantly in southern California and South Carolina. At the same time, the number of fledglings increased. Growth in the number of fledglings is a function of the lower concentrations of DDT in their primary food source, anchovies and other small fish, and habitat protection.

272 NTS

NTIS 273

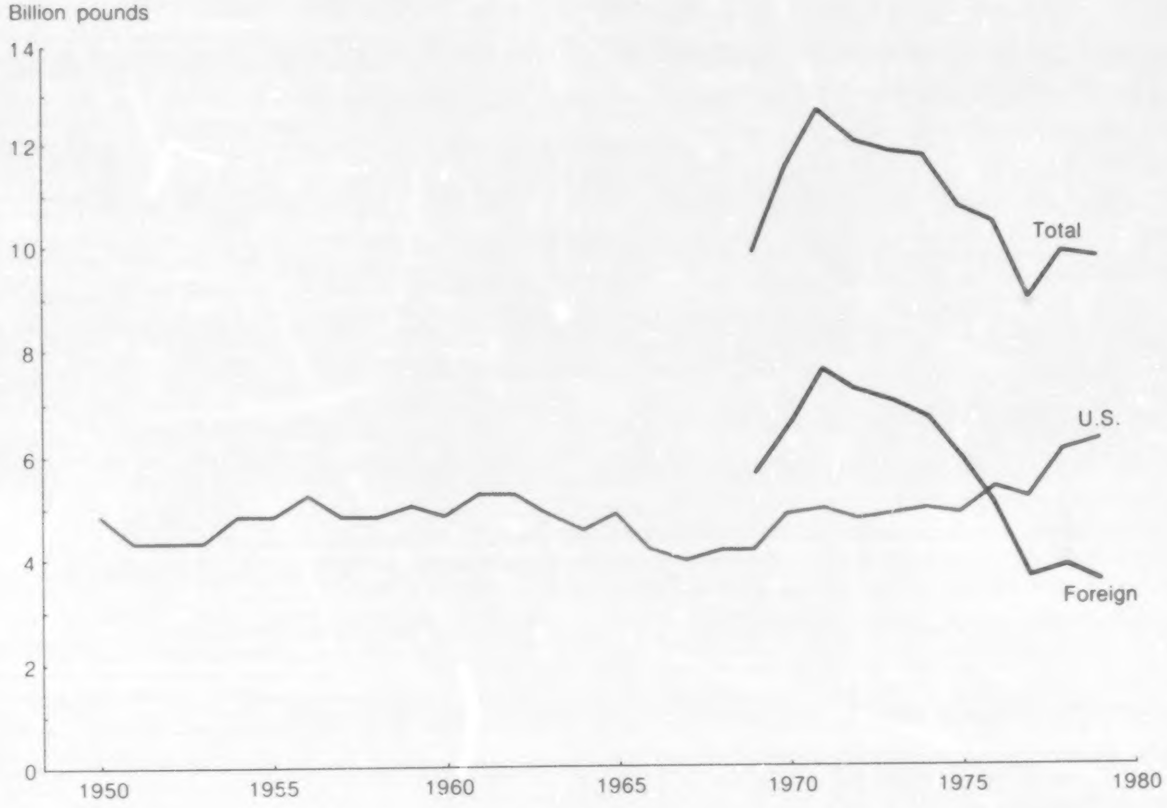
8-12
Distribution of fish species and major subspecies, by type of environment and region, 1970s


Pacific Coast
M
L
R
E
O
Total
11
100
132
139
124
236
Great Plains
M 133
L 158
R 156
E 0
O 0
Total 167
Rocky Mountains
M 104
L 130
R 185
E 1
O 0
Total 199
North Central
M 88
L 151
R 241
E 0
O 0
Total 262
Northeast
M 45
L 113
R 195
E 29
O 172
Total 208
33
120
158
505
Caribbean Islands
M 35
L 31
R 68
E 171
O 185
Total 215
Pacific Islands
M 8
L 17
R 28
E 5
O 8
Total 32
Alaska
M 10
L 28
R 51
E 42
O 31
Total 53
Number of species and subspecies
More than 350
175-349
30-174
Entire United States
M Marsh 289
L Lake 475
R River 720
E Estuary 449
O Ocean 460
Total 1,067

U.S. waters support more than 1,000 fresh water and marine fish species. With its warm climate, abundant rainfall, and extensive waterways and coastlines, the Southeast supports more than 500.

8-13

U.S. and foreign fish catch in U.S. waters, 1950–1979



The total commercial catch in U.S. waters declined during most of the 1970s. The peak was 12.7 billion pounds in 1971; in 1977, the catch was 8.9 billion pounds.

Catch by U.S. fishermen has changed little in 29 years, averaging 4.9 billion pounds per year. Foreign catch in U.S. waters, on the other hand, increased to 7.7 billion pounds in 1971 but has since declined to 3.6 billion pounds.

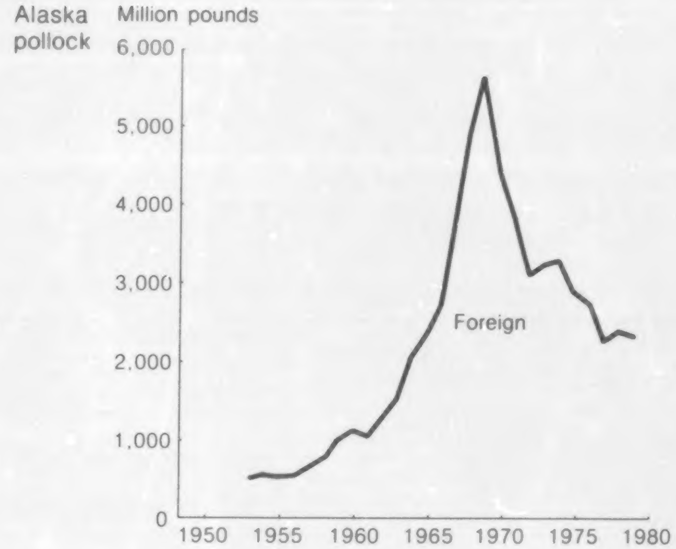
276 [illegible]

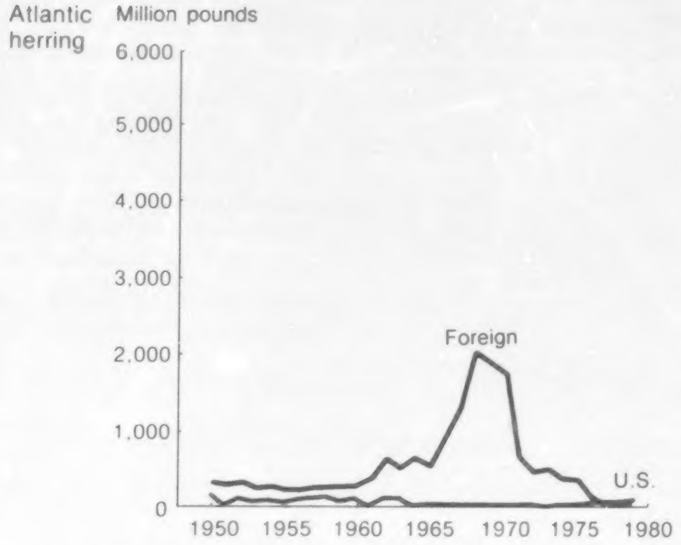
8-14
U.S. and foreign catch of selected fish species in U.S. waters, 1950–1979

Substituting new species and exploiting the more traditional ones at faster rates has enabled U.S. commercial fishermen to maintain levels of production. Yet about half the important commercial fisheries are showing signs of declining catches. As early as 1963, the Pacific halibut *(Hippoglossus stenolepis)* began showing signs of depletion, and catches declined steadily for 15 years. The haddock *(Melanogrammus aeglefinus)* and the Atlantic herring *(Clupea harengus harengus)* were overfished, and catches declined precipitously. Once a fish stock is depleted, the fleets move on, often causing another fishery to decline. So continues the cycle of exploitation and decline.

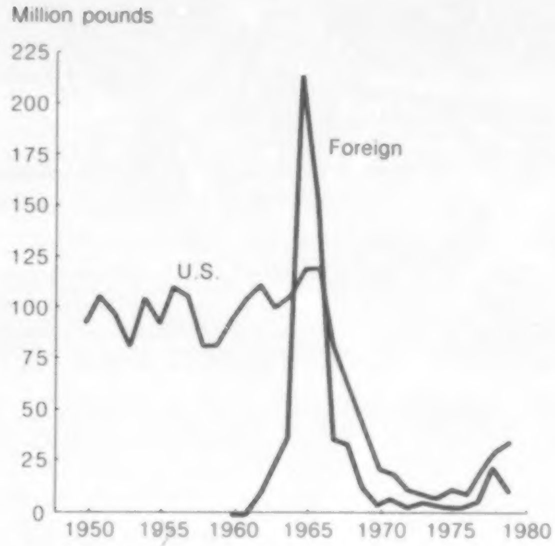
During the past century, many of the most desired species of salt and fresh water fish have been overexploited. It is not always known whether a given species will regain previous levels of abundance or will stabilize at low levels.

In an attempt to restore fish populations and fisheries, the Federal Government has set quotas on annual catches of these six species and other selected species since 1977. The haddock quota is 14 million pounds. If maintained, it is expected to raise annual sustained yield to 100 million pounds.

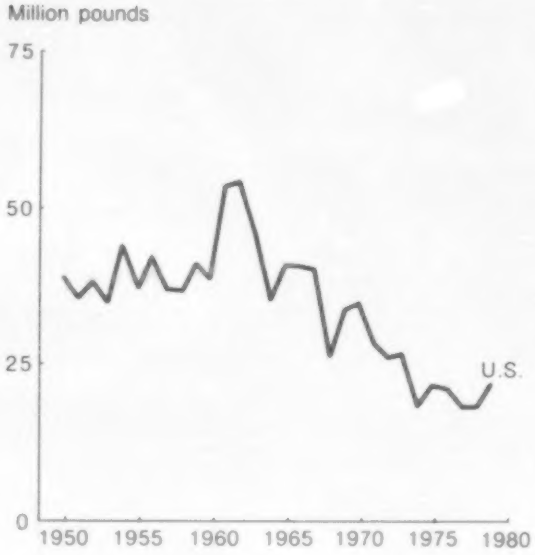




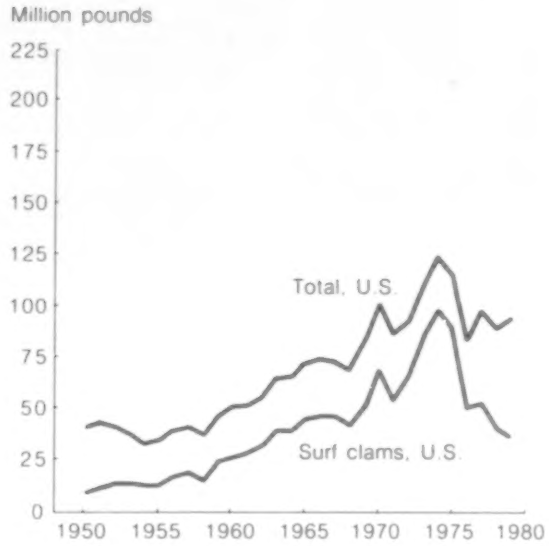
Haddock



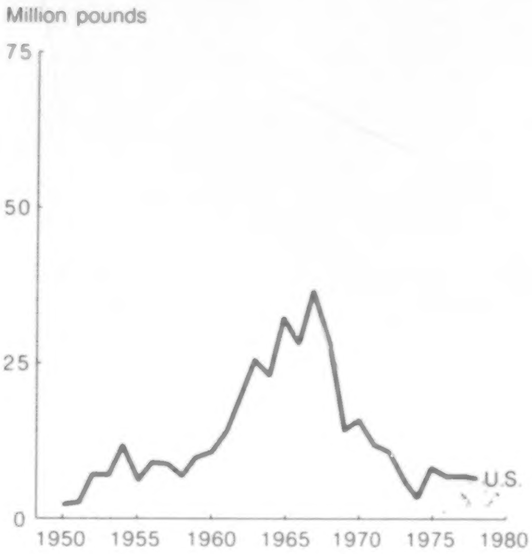
Pacific halibut



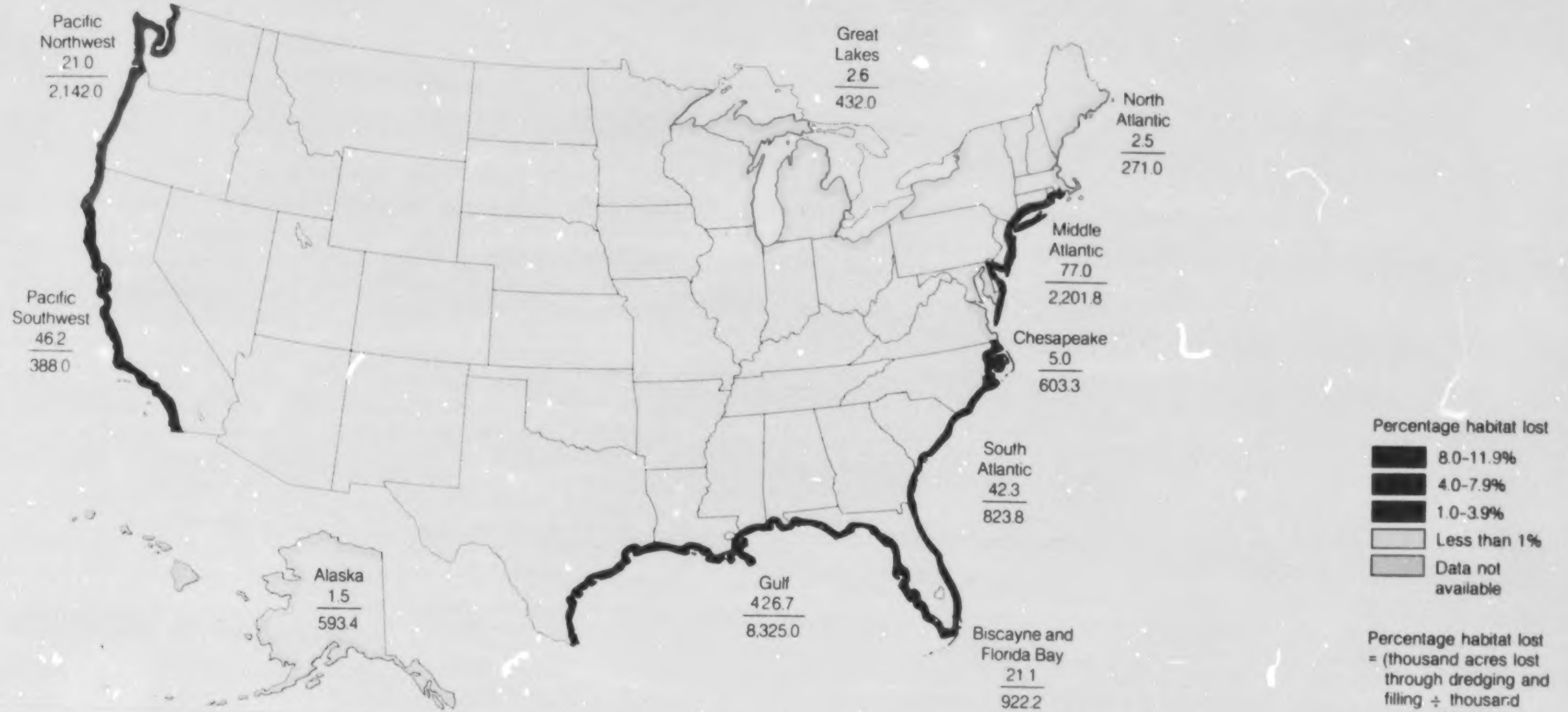
Clams



Pacific perch



8-15
Estuarine habitat lost to dredging and filling, 1950–1969


Pacific Northwest
21.0
2,142.0
Great Lakes
2.6
432.0
North Atlantic
2.5
271.0
Middle Atlantic
77.0
2,201.8
Chesapeake
5.0
603.3
Pacific Southwest
46.2
388.0
South Atlantic
42.3
823.8
Alaska
1.5
593.4
Gulf
426.7
8,325.0
Biscayne and Florida Bay
21.1
922.2
Percentage habitat lost
8.0-11.9%
4.0-7.9%
1.0-3.9%
Less than 1%
Data not available

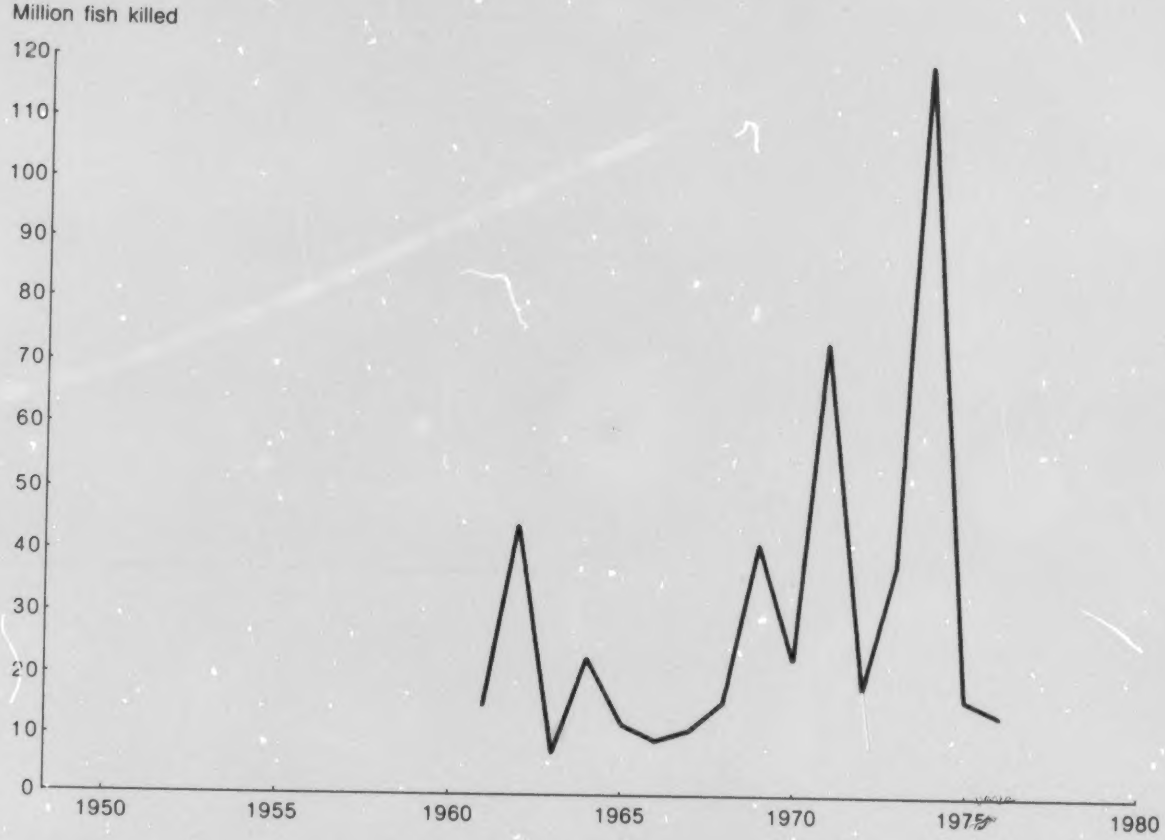
Percentage habitat lost = (thousand acres lost through dredging and filling ÷ thousand acres of important habitat)
For example:
$\frac{21.1}{922.2} = 2.3\%$

Fish stocks have also been reduced by the modification and destruction of natural habitat, by changes in salinity and sedimentation, by increased pollution, and by use of coastal waters for transportation and recreation.

The most lasting impact is destruction of estuarine habitat, the breeding and nursery grounds for shellfish and many other forms of aquatic life. Between 1950 and 1969, an estimated 646,000 acres (4.9%) of estuarine habitat were lost to dredging and filling.

8-16

Fish kills caused by pollution, 1961–1976

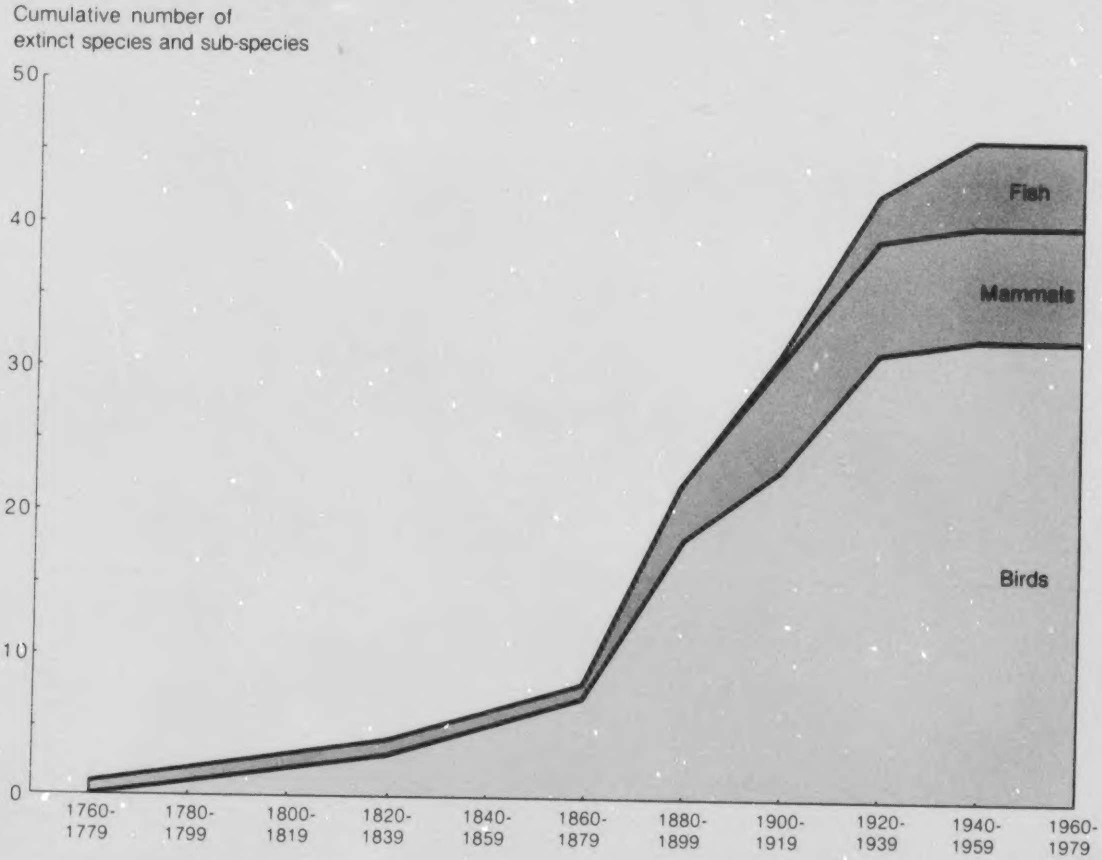


Between 1961 and 1976, 482 million fish were reported killed as a direct result of pollution. These reports, which are voluntary, probably account for only a fraction of the fish that were killed. Many small kills are not noticed or are not reported, and large kills are often not included because of insufficient information to determine whether the kills were caused by pollution or natural factors.

Kills of 1 million or more were responsible for 77% of all reported fish killed in the 15 years.

Low dissolved oxygen levels resulting from excessive sewage, primarily municipal, were the leading cause. The largest single incident was reported in 1974, when an estimated 47 million fish were killed by untreated sewage in the Back River near Essex, Maryland. The second most common cause was pesticides.

8-17
Extinct vertebrate species and subspecies, 1760–1979

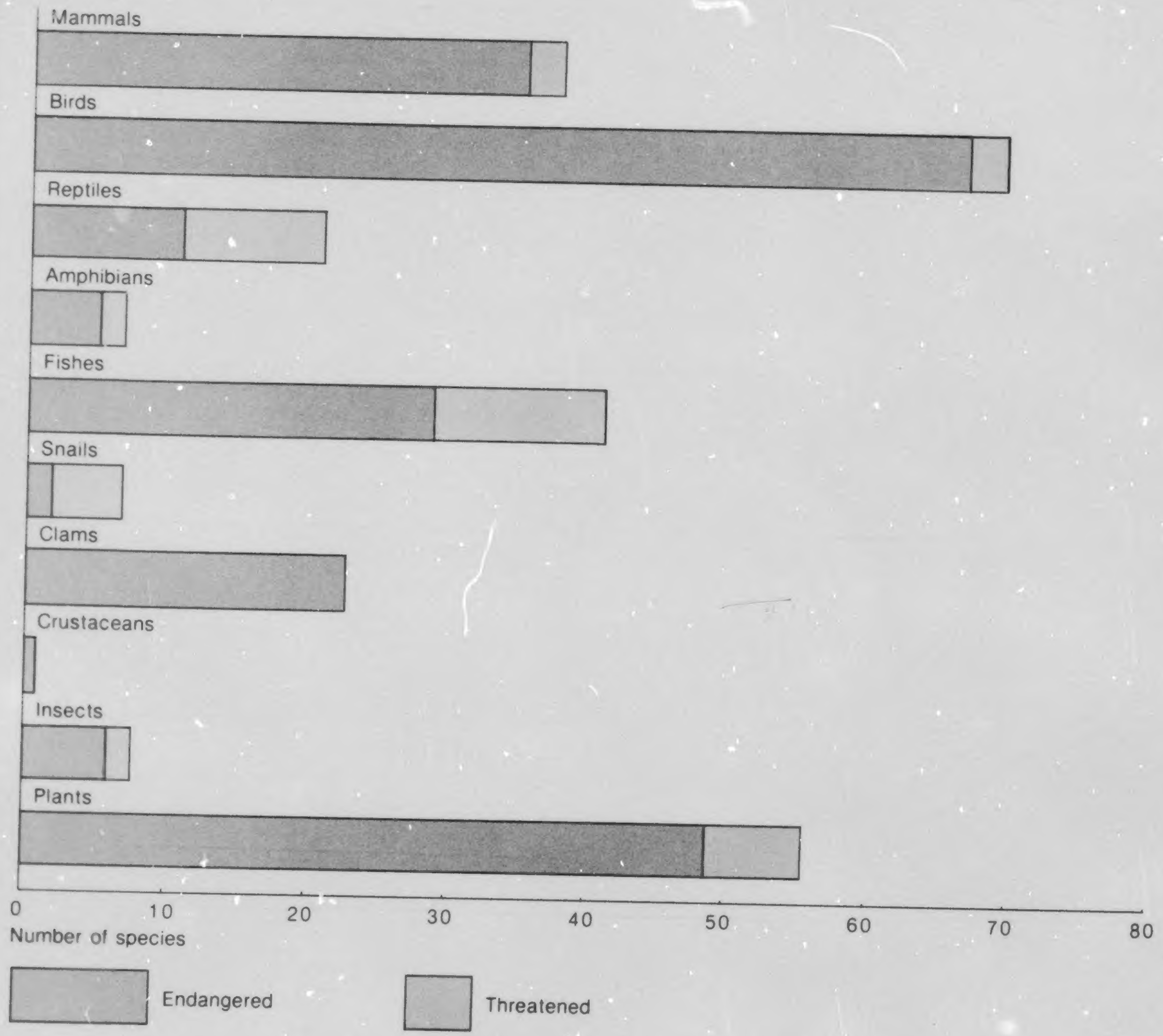


Since 1959, no species or subspecies of mammal, bird, or fresh water fish has been designated extinct. By 1900, 22 species of mammals, birds, and fish were lost, and between 1900 and 1960 another 24 were lost. Some of those lost include the eastern elk *(Cervus canadensis canadensis)* (1880s), the passenger pigeon *(Ectopistes migratorius)* (1890s), the Carolina parakeet *(Conuropsis carolinensis carolinensis)* (1920s), the plains wolf *(Canis lupus nubilus)* (1920s), and the Leon Springs pupfish *(Cyprinodon bovinus)* (1930s). These animals were hunted indiscriminately or their habitats destroyed.

The current rate of extinction of warm blooded vertebrates (20 or more birds and mammals per 100 years) is seven times that estimated for the late Pleistocene period, a time of great geological and ecological change at the end of the most recent ice age.

Complete and accurate records of extinct insects, crustaceans, and other invertebrates have not been kept. By official record, no reptiles and only one amphibian, the Vegas Valley leopard frog *(Rana pipiens fisheri)*, have been lost in the United States since European settlers arrived.

8-18
Threatened and endangered animal species in the United States, December 1979

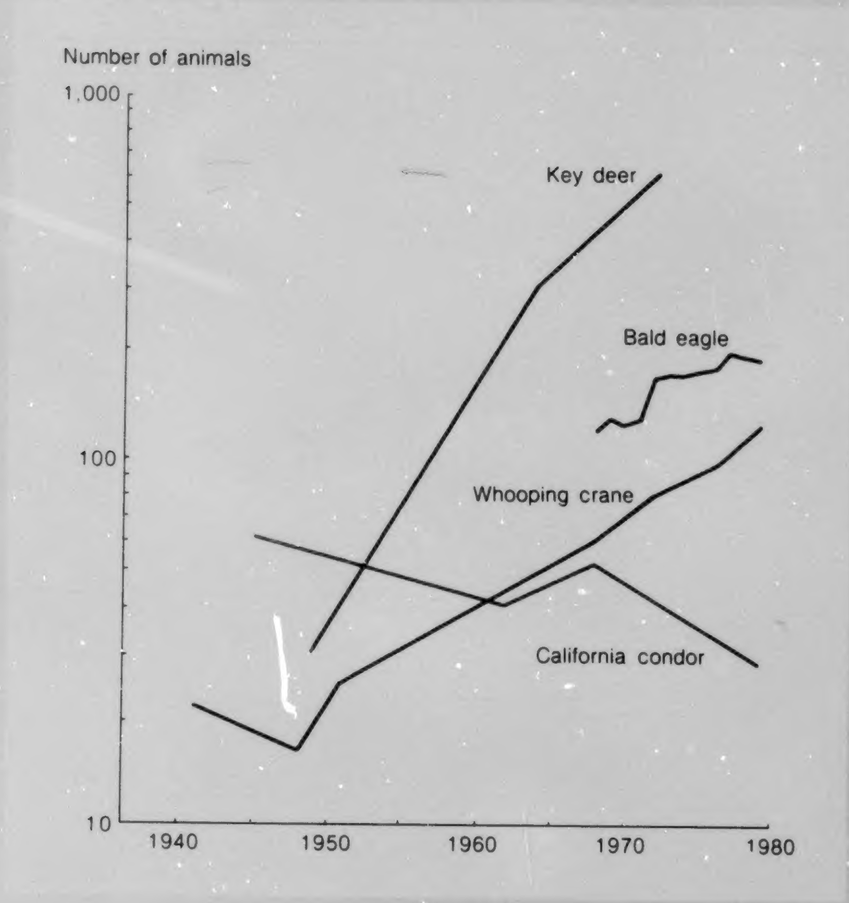


Many species of wildlife in the United States are dangerously close to extinction. At the end of 1979, 228 plant and animal species were listed as endangered; 44 were listed as threatened. Another 45 animal species had been proposed for designation and were under study.

The Endangered Species Act provides for their conservation and recovery. An endangered species is in danger of becoming extinct throughout all or a significant part of its natural range. A threatened species is likely to become endangered in the foreseeable future.

Species are determined endangered or threatened by the Secretary of the Interior. The States, the Smithsonian Institution, the U.S. Forest Service, and other administrative units have classified additional species as endangered, threatened, rare, or sensitive.

8-19
Population of selected threatened and endangered species, 1941-1979



Some species are recovering—the American alligator *(Alligator mississippiensis)*, the bald eagle *(Haliaeetus leucocephalus)*, the whooping crane *(Grus americana)*, and the Key deer *(Odocoileus virginianus clavium)* populations have increased significantly.

Others are losing ground despite conservation efforts. The California condor *(Gymnogyps californianus)* population was decimated in the 1800s and early 1900s, and the population has been declining since. Only about 30 birds now remain. The Florida panther *(Felis concolor coryi)* is also near extinction.

For some species it is too late. The black-footed ferret *(Mustela nigripes)* is probably extinct in the wild. The ivory-billed woodpecker *(Campehilus principalis principalis)* has not been definitely observed since the late 1940s. The red wolf *(Canis rufus)* population has declined because of excessive killing by man. The small remaining population is now hybridizing with coyotes and dogs, and the animals in captivity are of questionable genetic purity.

Under provisions of the Endangered Species Act, areas on which endangered and threatened species depend for survival may be designated critical habitats by the Secretary of the Interior. In these areas, Federal agencies must ensure that their activities do not adversely modify or destroy the habitat or jeopardize the continued existence of the species.

More than 100 critical habitats have been designated for 34 species. A few species—the whooping crane, for example—have several critical habitats which range from breeding grounds in the North to wintering grounds in the South with stopover areas between. Critical habitats range from 15 acres for the St. Croix ground lizard *(Ameiva polops)* to 4.6 million acres for the gray wolf *(Canis lupus)*.

Critical habitats are not closed to most human uses, only to activities which threaten the well-being of the species. Designation as critical habitat is based solely on biological factors, and it may cover private as well as public lands.

Very rarely are critical habitats designated for plant species because of the possible species destruction by souvenir hunters.

The snail darter *(Percina tanasi)* is the only species whose designated critical habitat has been destroyed. When the Tellico Dam on the Little Tennessee River was exempted from the Endangered Species Act, the last known (at that time) natural area for the snail darter was flooded. Although two other rivers in Tennessee have been stocked with the snail darter, neither has yet been designated a critical habitat.

8-20

Condition of selected threatened and endangered species

Species	Status	Estimated population	Year	Habitat	Causes for decline, comments
Mammals					
Florida panther *Felis concolor coryi*	E	100-300 10-15	1940s/1960s 1978	Florida's Big Cypress Swamp	Overhunting
Eastern timber wolf *Canis lupus lycaon*	E/T	832-1,332 + 22 in captivity 1,000-1,200	1969/1970 1978	Primarily Minnesota Population includes only 48 states	Hunting and trapping, modification of habitat. Stable population in Minnesota
Red wolf *Canis rufus*	E	16 in captivity	c. 1969	Formerly Texas and Louisiana coasts	Trapping, hunting, disease
San Joaquin kit fox *Vulpes macrotis mutica*	E	1,000-3,000	1970	Foothills below 2,000 feet, western San Joaquin Valley, California, areas of native vegetation	Destruction of habitat, illegal shooting, trapping
Black-footed ferret *Mustela nigripes*	E	31-32 + 3 in captivity	1950s/1960s	Western North Dakota, South Dakota, northern Montana; Alberta, Canada, central New Mexico	Predation by prairie dogs, destruction of habitat
Grizzly bear *Ursus arctos*	T	850 695-1,020	1960s 1970	Colorado, Idaho, Montana, Washington, Wyoming	Expanding human activity
Utah prairie dog *Cyonmys parvidens*	E	5,715	1972	South central Utah	Disease, damage to habitat
Delmarva Peninsula (Bryant) fox squirrel *Sciurus niger cinereus*	E	468 100-200	1960s 1979	Southeastern Maryland Chincoteague National Wildlife Refuge	Destruction of habitat
Key deer *Odocoileus virginianus clavium*	E	30 300 600	1949 1964 1972	Florida Keys	Destruction of habitat, hurricanes, fires, overhunting. Slowly increasing over a small range
West Indian manatee (Florida) *Trichechus manatus*	E	1,000	1978	Florida coastal waters	Excessive killing, habitat loss, boat accidents
Birds					
Eastern brown pelican *Pelecanus occidentalis carolinensis*	E	16,000	1977	Southeastern Atlantic coast, Texas coast	Reproduction impairment (thin egg shells), primarily from pesticides (DDT and dieldrin) in food
California brown pelican *Pelecanus occidentalis californicus*	E	100,000 including Mexico	1972	Pacific coastal islands	Reproduction impairment (thin egg shells), primarily from pesticides (DDT and dieldrin) in food
Aleutian Canada goose *Branta canadenis leucopareia*	E	1,600	1977	Breeds in western Aleutians; Winters in California's central valley	Reduction of secure breeding range caused by predation by arctic foxes *(Alopex lagopus)*
California condor *Gymnogyps californianus*	E	60 40 51-53 25-30	1940s early 1960s late 1960s 1979	Mountains north of Los Angeles	Land development, decreasing food supply, pesticides, pollution

8-20 *(continued)*

Condition of selected threatened and endangered species

Species	Status	Estimated population	Year	Habitat	Causes for decline, comments
Whooping crane *Grus americana*	E	2,000-4,000	Pre-settlement	Breeds in Wood Buffalo National Park, Mackenzie, Canada; winters on Texas coast, occasionally in Mexico	Shooting, reduction of breeding habitat prior to 1940s
		1,300	mid 1800s		
		21	1941		
		16	1948		
		25	1950-1952		
		60	late 1960s		
		80	1972		
		96	1976		
		120-125, including 29 in captivity	1979		
Mississippi sandhill crane *Grus canadensis pulla*	E	39-40, including 9 in captivity	1970	Jackson County, Mississippi	Modification of habitat
		45-48	1978		
Puerto Rico parrot *Amazon vittata*	E	19	1975	Luquillo Mountains, Puerto Rico	Destruction of habitat, competition for nesting sites; taking as pets; disease; shooting
		22	1976		
		18	1977		
		26-28 + 15 in captivity	1978		
		25 + 15 in captivity	1979		
Bald eagle *Haliaeetus leucocephalus*	E/T	more than 1,300 nesting pairs	1979	Primarily Chesapeake, Northwest, Great Lakes estuarine areas. Population includes only 48 states.	Destruction of habitat, pesticides in food
		119 nesting pairs	1968	In National Forests of Michigan, Wisconsin, and Minnesota.	
		188 nesting pairs	1979		
American peregrine falcon *Falco peregrinus anaturn*	E	120-150 + 200 in captivity	1979	Breeds from non-arctic Alaska, south to Baja California, to eastern Rocky Mountains. Population includes only 48 states.	Reproduction impairment (thin egg shells), primarily from pesticides (DDT and dieldrin) in food
Arctic peregrine falcon *Falco peregrinus tundrius*	E	2,000-6,000 breeding pairs	1960s	Treeless tundra of arctic Alaska, Canada, western Greenland	Reproduction impairment (thin egg shells), primarily from pesticides (DDT and dieldrin) in food
Attwater's greater prairie chicken *Tympanuchus cupido attwateri*	E	2,200	1971	Texas coastal prairie	Destruction of habitat
Red-cockaded woodpecker *Dendrocopos borcalis*	E	3,000-10,000	1970	Open, old pine woodlands from southeastern Oklahoma, Texas, western Kentucky, southeastern Virginia to southern Florida	Reduction of habitat
		less than 1,000	1979		
Reptiles/Amphibians					
Houston toad *Bufo houstonensis*	E	1,000-1,500	1978	Southeastern Texas	Destruction of habitat, hybridization

Species	Status	Estimated population	Year	Habitat	Causes for decline, comments
Green turtle *Chelonia mydas*	E	less than 100 mature adults	1978	Southeastern Florida coast, Mexico (Threatened worldwide.)	Commercial exploitation, beach development
Kemp's ridley sea turtle *Lepidochelys kempi*	E	40,000 nesting females 500-1,000 nesting females	1947 1979	Nesting habitat: Rancho Nuevo, Mexico; Padre Island National Seashore, Texas	Predation, poaching
American alligator *Alligator mississippiensis*	E/T	52,165 1 million + several thousand in captivity	1970 1979	North Carolina, Texas, Mississippi, Arkansas, southeastern California	Commercial exploitation, destruction of habitat prior to 1970; great population increase in 1970s
American crocodile *Crocodylus acutus*	E	1,000-2,000 100-400	1900 1979	Southern Florida	Urbanization, destruction of habitat
Fishes					
Snail darter *Percina tanasi*	E	3,000	late 1970s	Originally in Little Tennessee River, Tennessee; late 1970s, stocked in Hiwassee River, Holston River, Tennessee	Loss of habitat
Plants					
Harperocallis flava	E	less than 100*	1979	Apalachicola National Forest, Florida	Changes in land management, vandalism, harvest by collectors
Kokia cookei	E	1 in cultivation	1979	Formerly western Molokai, Hawaiian Islands	Destruction of habitat; grazing by cattle, goats
Ancistrocactus tobuschii	E	less than 200*	1979	Stream banks and loose gravel bars, central Texas	Harvest by collectors, natural flooding
Echinocereus kuenzleri	E	less than 200*	1979	Central New Mexico highlands	Highway construction, harvest by collectors
Sclerocactus glaucus	T	15,000*	1979	Western Colorado and eastern Utah plateaus	Harvest by collectors, recreational use of high desert
Arctostaphylos hookeri ssp. *ravenii*	E	1*	1979	San Francisco Presidio	Human trampling, competition from nonnative species
Stenogyne angustifolia var. *angustifolia*	E	less than 100*	1979	Hawaiian Islands	Grazing; browsing; human trampling; exotic weeds, plants

*Excludes specimens in cultivation

E — Endangered
T — Threatened
E/T — Endangered or threatened, depending on location

8-1
Distribution of vertebrate species and major subspecies, by region, 1970s

An assessment of the forest and rangeland situation in the United States, USDA Forest Service (Washington: USGPO, 1979), fig. 4.1, p. 166.

Includes resident and common migrant vertebrate species and selected subspecies which are listed by the Federal or a State government as endangered or threatened, are judged sensitive to land or water management practices, and are of commercial or recreational importance.

Regions are those of the USDA Forest Service.

Regional details do not add to U.S. totals because double counting of species and major subspecies has been eliminated.

8-2
Selected large mammal populations on Bureau of Land Management lands, 1961–1975

Public land statistics 1976, U.S. Department of the Interior (Washington: USGPO, 1977), p. 84, and previous annual issues.

The Bureau of Land Management manages 450 million acres.

Data for pronghorn antelope do not include Alaska.

8-3
Selected large mammal populations in National Forests and National Grasslands, 1960–1978

Annual wildlife and fisheries report 1978, USDA Forest Service (Washington: USGPO, 1979), and previous annual issues.

Data are limited to National Forests and Grasslands and may therefore exclude significant populations of these species, for example, the caribou found in the Arctic Wildlife Refuge.

The National Forests and Grasslands total 187 million acres.

8-4
Animals removed or killed by Federal predator control activities, 1937–1978

1937–1970: *Predator control 1971*, Advisory Committee on Predator Control (Washington: USGPO, 1972), p. 22.

1971–1977: U.S. Fish and Wildlife Service, Animal Damage Control Division, unpublished data.

Years are fiscal years.

Some hybrid animals, for example, red wolf/coyote and red wolf/dog, are included.

Federal funding for taking red wolves ended in 1964; it ended for the timber wolf in 1971. Both are now endangered, although for the timber wolf, endangerment does not include those in Alaska.

8-5
Bird species observed, 1968–1977

U.S. Fish and Wildlife Service, Migratory Bird and Habitat Research Laboratory, Breeding Bird Survey, unpublished data.

The Fish and Wildlife Service's annual Breeding Bird Survey measures the number and abundance of bird species. North America is divided into 62 ecological regions. All birds seen or heard within a quarter-mile radius during fifty 3-minute stops spaced at half-mile intervals along randomly selected 24.5-mile routes, of which there are 2,300, are counted. One-degree blocks of latitude and longitude are used as a basis for route selection to ensure good geographic distribution of the routes. Both starting point and direction of travel for 1 to 16 routes within each block are determined from a table of random numbers. The survey is described in "Ecological distribution of breeding birds," Steven R. Peterson, *Proceedings of the symposium on management of forest and range habitats for nongame birds, May 6–9, 1975, Tucson, Ariz.*, USDA Forest Service (Washington, D.C., 1975), gen. tech. rep. WO-1, pp. 22–38.

8-6
Selected bird species populations, 1966–1977

See 8-5.

8-7
Most frequently observed breeding bird species, 1977

See 8-5.

The house sparrow and starling were introduced to North America.

8-8
Distribution of North American breeding and wintering ducks, 1970s

Waterfowl habitat trends in the Aspen Parkland of Manitoba, William H. Kiel, Jr., Arthur S. Hawkins, Noland G. Perret, Canadian Wildlife Service (Ottawa: Information Canada, 1972), rep. series 18, fig. 7, p. 54.

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8-9
Duck breeding populations in North America, 1955–1979

The status of waterfowl and fall flight forecasts 1979, U.S. Fish and Wildlife Service and Canadian Wildlife Service (Laurel, Md., 1979), fig. 3.

Duck breeding populations are counted from late April until early June.

Population includes mallards *(Anas platyrhynchos)*, gadwalls *(Anas strepera)*, pintails *(Anas actua)*, green-winged teals *(Anas crecca)*, blue-winged teals *(Anas discors)*, American wigeons *(Anas americana)*, northern shovelers *(Anas clypeata)*, redheads *(Aythya americana)*, canvasbacks *(Aythya valisineria)*, scaups *(Aythya affinis, Aythya marila)*, and others; it excludes eiders, oldsquaws, scoters, and mergansers.

8-10
Duck harvest, by flyway, 1952–1978

1952–1977: U.S. Fish and Wildlife Service, Office of Migratory Bird Management, memorandum from Biologist, Waterfowl Harvest Survey Section to Chief, June 6, 1979.

1978: "Waterfowl harvest and hunter activity in the United States during the 1978 hunting season," Samuel M. Carney et al., U.S. Fish and Wildlife Service, Office of Migratory Bird Management, administrative report, June 21, 1979, table 1.

The harvest year extends from the fall of one year through the following winter; for example, 1952 begins in autumn 1952 and ends in winter 1953.

Data for 1978 are estimated.

Data include ducks bagged and unretrieved kill.

Harvest data include mallards *(Anas platyrhynchos)*, black ducks *(Anas rubripes)*, gadwalls *(Anas strepera)*, pintails *(Anas acuta)*, green-winged teals *(Anas crecca)*, blue-winged teals *(Anas discors)*, wood ducks *(Aix sponsa)*, American wigeons *(Anas americana)*, northern shovelers *(Anas clypeata)*, redheads *(Aythya americana)*, canvasbacks *(Aythya valisineria)*, ring-necked ducks *(Aythya collaris)*, scaups *(Aythya affinis, Aythya marila)*, goldeneyes *(Bucephala clangula, Bucephala islandica)*, buffleheads *(Bucephala albeola)*, eiders *(Somateria mollissima, Somateria spectabilis, Polysticta stelleri)*, oldsquaws *(Clangula hyemalis)*, scoters *(Melanitta nigra, Melanitta deglandi, Melanitta perspicillata)*, ruddy ducks *(Oxyura jamaicensis)*, mergansers *(Mergus merganser, Mergus serrator, Lophodytes cucullatus)*, and other ducks.

The total includes 0.05 to 0.14 million ducks harvested annually in the Alaska flyway.

8-11
Brown pelican populations and toxic residues in eggs, 1969–1976

Southern and Baja California, 1969–1974, fledglings and DDT residues: "Brown pelicans: Improved reproduction off the southern California coast," Daniel W. Anderson et al., *Science* 190:807 (1975). 1975 data and PCB residues: "The status of brown pelicans at Anacapa Island in 1975," Daniel W. Anderson et al., *California Fish and Game* 63:6 (1977).

South Carolina: "Effects of organochlorine residues on eggshell thickness, reproduction, and population status of brown pelicans in South Carolina and Florida, 1969–1976," Lawrence J. Blus, Thair B. Lamont, and Burkett S. Neely, Jr., *Pesticides Monitoring J.* 12(4): 173, 182 (1979), tables 1, 9.

Residues are the geometric mean concentration in eggs, parts per million lipid weight.

Areas in southern California and northwestern Baja California include Anacapa and Santa Cruz islands and Isla Coronado Norte.

Areas in South Carolina were Marsh Island in the Cape Romain National Wildlife Refuge and Deveaux Bank.

8-12
Distribution of fish species and major subspecies, by type of environment and region, 1970s

See 8-1, p. 186.

Regions are those of the USDA Forest Service.

A given species may be found in several environments, which are classified as suggested in *Classification of wetlands and deep water habitats of the United States*, L. M. Cowardin, F. C. Golet, and E. T. LaRoe, U.S. Fish and Wildlife Service (Washington, D.C., 1977), p. 100.

Regional details do not add to U.S. totals because double counting of species and major subspecies has been eliminated.

8-13
U.S. and foreign fish catch in U.S. waters, 1950–1979

U.S. catch: *Fisheries of the United States, 1979*, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (Washington: USGPO, 1980), pp. 6, 24.

Foreign catch, 1969–1976: National Marine Fisheries Service, unpublished data. 1977: *Fisheries of the United States, 1978* (Washington: USGPO, 1979), p. 12. 1978–1979: *Fisheries of the United States, 1979* (Washington: USGPO, 1979), pp. 12, 13.

U.S. waters extend out 200 miles from the coast.

U.S. catch excludes weight of mollusk shells: 1970–1979 data are fish landings, not catch.

8-14
U.S. and foreign catch of selected fish species in U.S. waters, 1950–1979

Pacific halibut, 1950–1979: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, unpublished data.

Haddock, 1950–1955: *The United States marine fishery resource*, John P. Wise, ed. (Washington: USGPO, 1976), MARMAP contrib. 1, p. 98. 1956–1976: "Review and assessment of the Georges Bank and Gulf of Maine haddock fishery," Stephen H. Clark and William J. Overholtz (Woods Hole, Mass.: National Marine Fisheries Service, 1980), lab. ref. 79-05, table 1. 1977–1979: "Georges Bank and Gulf of Maine haddock assessment update," Stephen H. Clark and Ronald J. Essig (Woods Hole, Mass.: National Marine Fisheries Service, 1980), lab. ref. 80-06, table 1. Foreign, 1960–1976: Clark and Overholtz, table 1; 1977–1979: Clark and Essig, table 1.

Clams, total, 1950–1965, and surf, 1950–1965: National Marine Fisheries Service, unpublished data. 1966–1975: *A comprehensive review of the commercial clam industries in the United States*, National Marine Fisheries Service (Washington: USGPO, 1977), p. 47. 1976–1978: *Fisheries of the United States, 1978*, National Marine Fisheries Service (Washington: USGPO, 1979), p. 2, and previous annual issues.

1979: National Marine Fisheries Service, unpublished data.

Alaska pollock, 1953–1970: Wise, p. 194. 1971–1979: National Marine Fisheries Service, unpublished data.

Atlantic herring, 1950–1970: Wise, p. 129. 1971–1972, domestic: Wise, p. 352. 1973–1978, domestic: *Fisheries of the United States, 1978* (Washington: USGPO, 1979), p. 1, and previous annual issues. 1971–1976, foreign: National Marine Fisheries Service, unpublished data. 1977–1978, foreign: *Fisheries of the United States, 1978* (Washington: USGPO, 1979), pp. viii, 14. 1979, domestic and foreign: *Fisheries of the United States, 1979* (Washington: USGPO, 1980) p. 8.

Pacific perch, 1950–1972: Wise, pp. 183, 352. 1973–1978: *Fisheries of the United States, 1978* (Washington: USGPO, 1979), p. 1, and previous annual issues.

Management data by species are available as follows: Pacific halibut—42 Fed. Reg. 8782, 9298 (1977), 43 Fed. Reg. 17242 (1978). Haddock—42 Fed. Reg. 13998 (1977). Clams—42 Fed. Reg. 60438 (1977). Alaska pollock—43 Fed. Reg. 17242 (1978). Atlantic herring—43 Fed. Reg. 60474 (1978). Pacific perch—42 Fed. Reg. 8578, 8782, 9298 (1977), 43 Fed. Reg. 17242 (1978), 44 Fed. Reg. 66356 (1979).

8-15
Estuarine habitat lost to dredging and filling, 1950–1969

National estuary study, U.S. Fish and Wildlife Service (Washington: USGPO, 1970), v. 2, appendix A, staff report.

Data include all water depths, except in the Great Lakes, where the water included was 6 feet or less.

8-16
Fish kills caused by pollution, 1961–1976

Fish kills caused by pollution in 1976, EPA Office of Water Planning and Standards (Washington: USGPO, 1979), pp. 4, 5.

8-17
Extinct vertebrate species and subspecies, 1760–1979

Threatened wildlife of the United States, U.S. Fish and Wildlife Service (Washington: USGPO, 1973), pp. 1–4.

The Tecopa pupfish *(Cyprinodon nevadensis calidae)* and the Santa Barbara song sparrow *(Melospiza melodia graminer)* are believed to be extinct and will be removed from the list of endangered and threatened species. As of December 1979, neither had been declared extinct and removed officially.

The passenger pigeon was extirpated from the wild in the 1890s, and the last known specimen died in the Cincinnati Zoo in 1914.

Dates refer to the last sighting, not to an official announcement of extinction. A species is often believed extinct several decades before official declaration by the U.S. Fish and Wildlife Service.

8-18
Threatened and endangered animal species in the United States, December 1979

U.S. Fish and Wildlife Service, Office of Endangered Species, *Endangered Species Tech. Bull.* 5(1):12 (1980).

For a species to be designated endangered or threatened, a qualified individual or group first brings the species to the attention of the U.S. Fish and Wildlife Service, which determines whether it is in fact threatened with extinction.

If extinction is possible because of habitat destruction or modification, overexploitation, disease, or predation and if its survival requires human assistance, it will be designated endangered or threatened. Then a plan to restore the population to sustainable levels is prepared and the remaining animals or plants are protected and managed.

The official Federal list of endangered and threatened species is periodically revised and published in the *Federal Register*.

Through cooperative agreements, States are provided matching funds for conservation of listed species. In addition, the U.S. Fish and Wildlife Service has established recovery teams which prepare recovery plans.

8-19

Population of selected threatened and endangered species, 1941-1979

Key deer, 1949-1972, and whooping crane, 1972: *Threatened wildlife of the United States*, U.S. Fish and Wildlife Service (Washington: USGPO, 1973), p. 265.

Whooping crane, 1941-late 1960s and 1976-1979, and California condor, 1979: U.S. Fish and Wildlife Service, Office of Endangered Species, unpublished data.

California condor, 1940s-late 1960s: *Predator control—1971*, Advisory Committee on Predator Control (Washington: USGPO, 1972), p. 86.

Bald eagle, 1969-1979: "Bald eagle-osprey survey report 1979," USDA Forest Service, prepared 1979, unpublished.

Data for the bald eagle include nesting pairs in the National Forests of Michigan, Wisconsin, and Minnesota.

8-20

Condition of selected threatened and endangered species

Threatened wildlife of the United States, U.S. Fish and Wildlife Service (Washington: USGPO, 1973), pp. 7, 88, 102, 104, 124, 127, 129, 133, 138, 141, 162, 217, 220, 237, 241, 242, 243, 245, 247, 265.

U.S. Fish and Wildlife Service, Office of Endangered Species, *Endangered Species Tech. Bull.*, Jan., Feb., March, April, May, Oct., Nov. 1979; Feb. 1980.

Predator control—1971, Advisory Committee on Predator Control (Washington: USGPO, 1972), pp. 86, 149, 154, 156.

U.S. Fish and Wildlife Service, Office of Endangered Species, unpublished data.

300

Chapter 9

Energy

Plentiful, low-cost energy is one of the foundations on which industrial society is built. Use of this energy has reduced physical labor, extended transportation to almost all areas of the continent, and provided light, heat, cooling, and appliances that make life comfortable.

The interaction of readily available energy and advanced technology largely determines the U.S. life style. It influences the construction, heating, and cooling of homes and the size, style, and operation of motor vehicles, motor homes, motorcycles, and snowmobiles. Until 1973, the real price of domestically produced fuels was declining, making it advantageous to put more energy to work, to make and transport goods, even to play.

The United States uses a third of all the energy used in the world in a given year, more than any other country. Its per capita use of energy is among the highest.

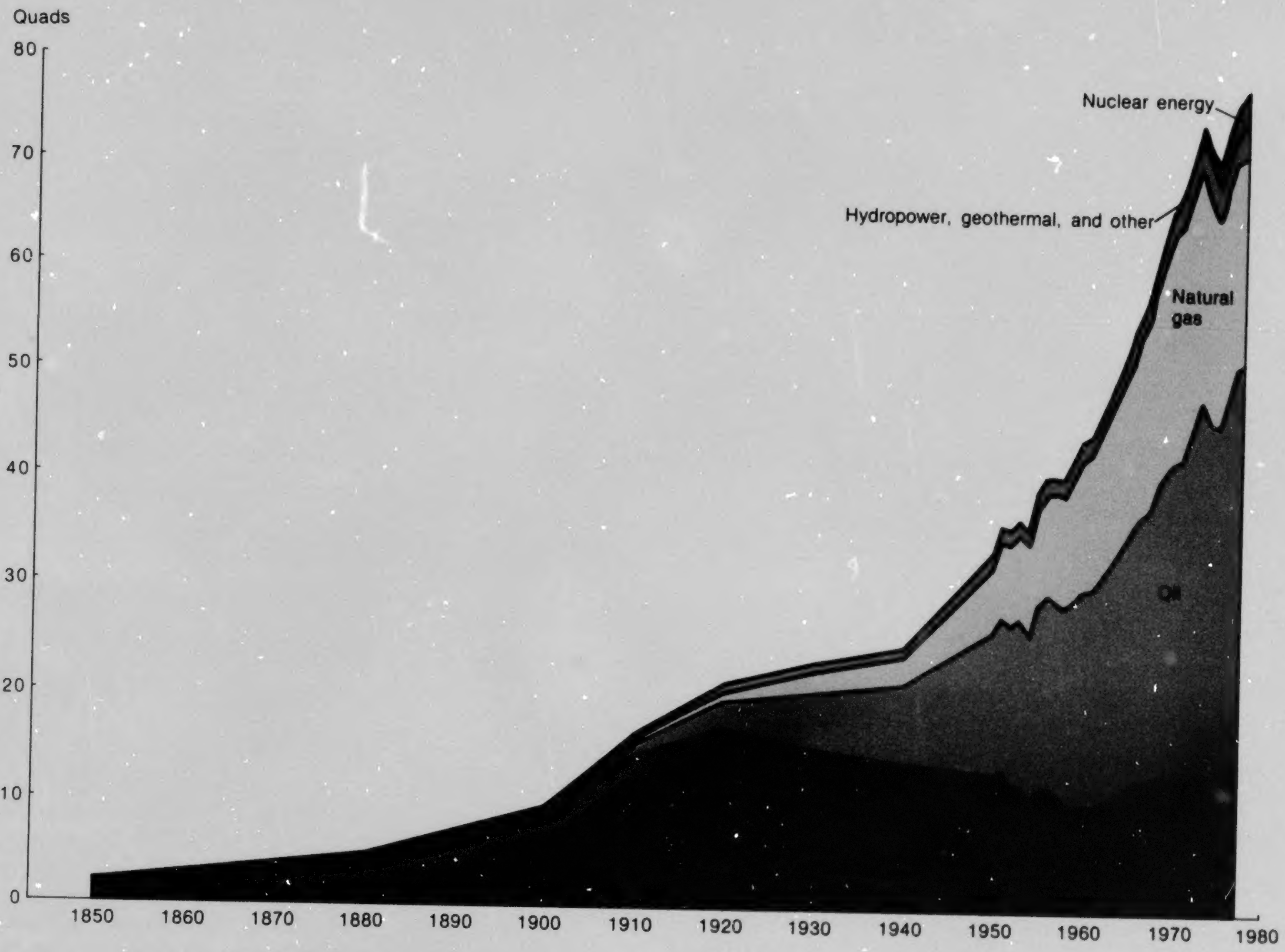
The environmental costs of this energy use have been high. They include health risks from air pollution and radioactive contamination, disturbed land, lost wilderness, destroyed wildlife, and polluted streams.

Historically, the Nation has had abundant, cheap energy resources—wood, coal, oil, and gas. As a consequence, there has been little incentive to use energy efficiently. But now, energy is coming to be viewed as a resource to be conserved and used wisely.

301

9-1

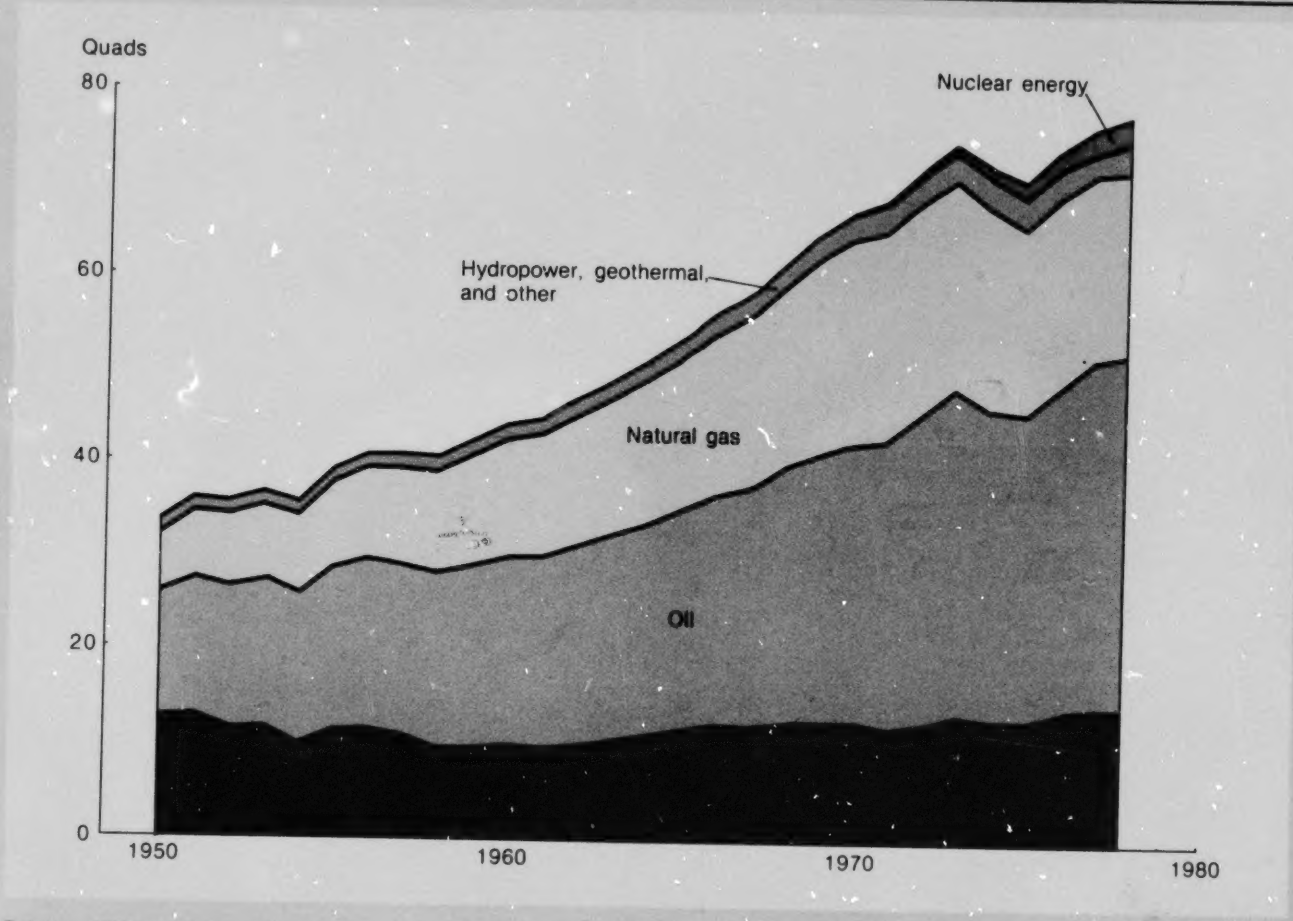
Energy consumption, by fuel type, 1850–1978



302

303

9-2
Energy consumption, by fuel type, 1950–1978



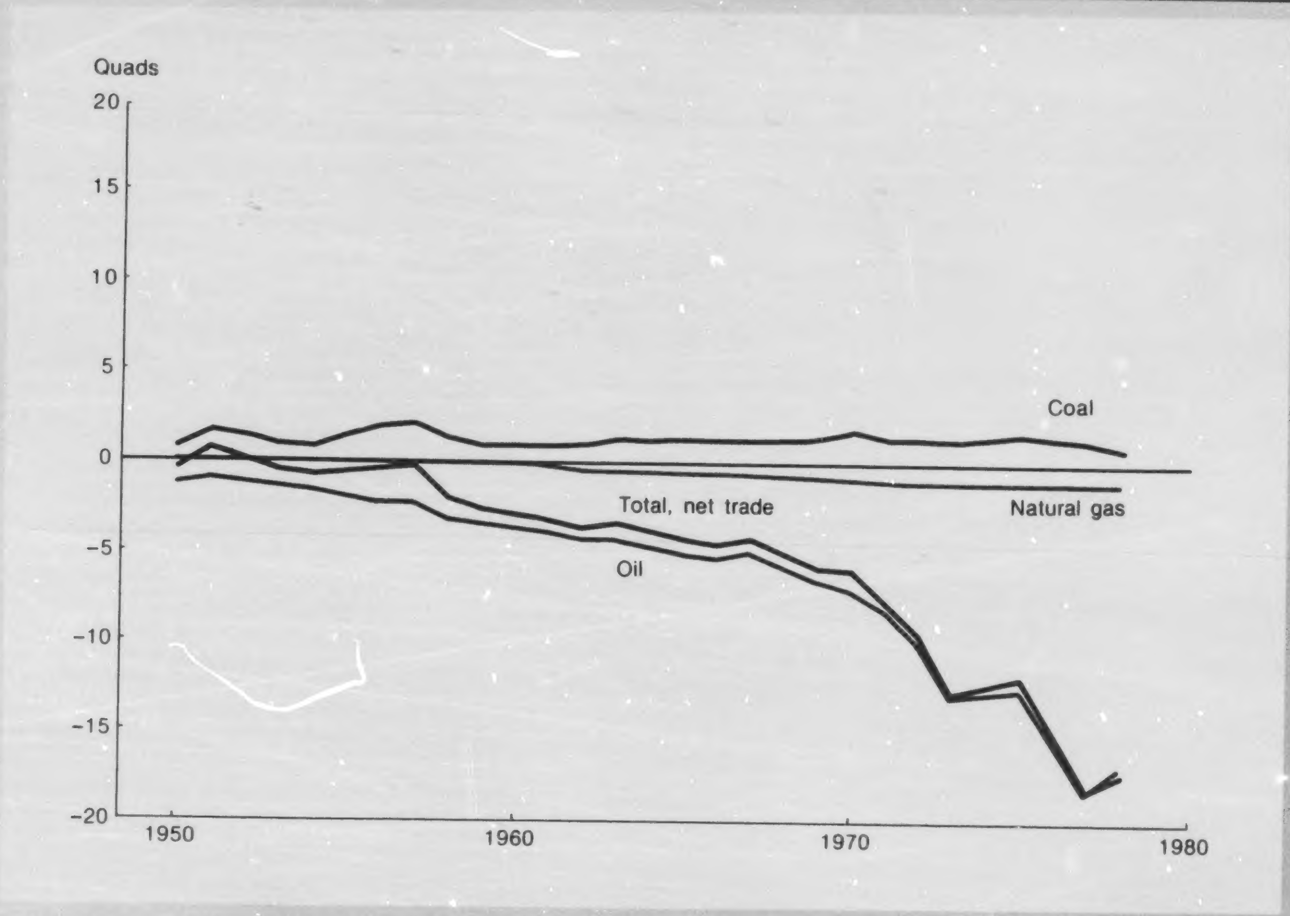
U.S. consumption of energy has increased more than 30-fold since 1850. In 1978, it was 78 quads.

A quad equals one quadrillion British thermal units (Btu). A Btu is the amount of energy required to raise the temperature of one pound of water 1°F at or near its point of maximum density, 39.2°F.

Between 1950 and 1973, energy consumption increased at an average annual rate of 3.5%. Petroleum and natural gas consumption increased by 4.3% and 5.9%, respectively.

Since 1973, the pattern has changed. Energy use declined in 1974 and 1975 in response to higher prices, the decline in economic activity, and changing public attitudes. Since 1975, energy consumption has again increased but at rates somewhat lower than before.

9-3
Net trade in energy resources, 1950–1978

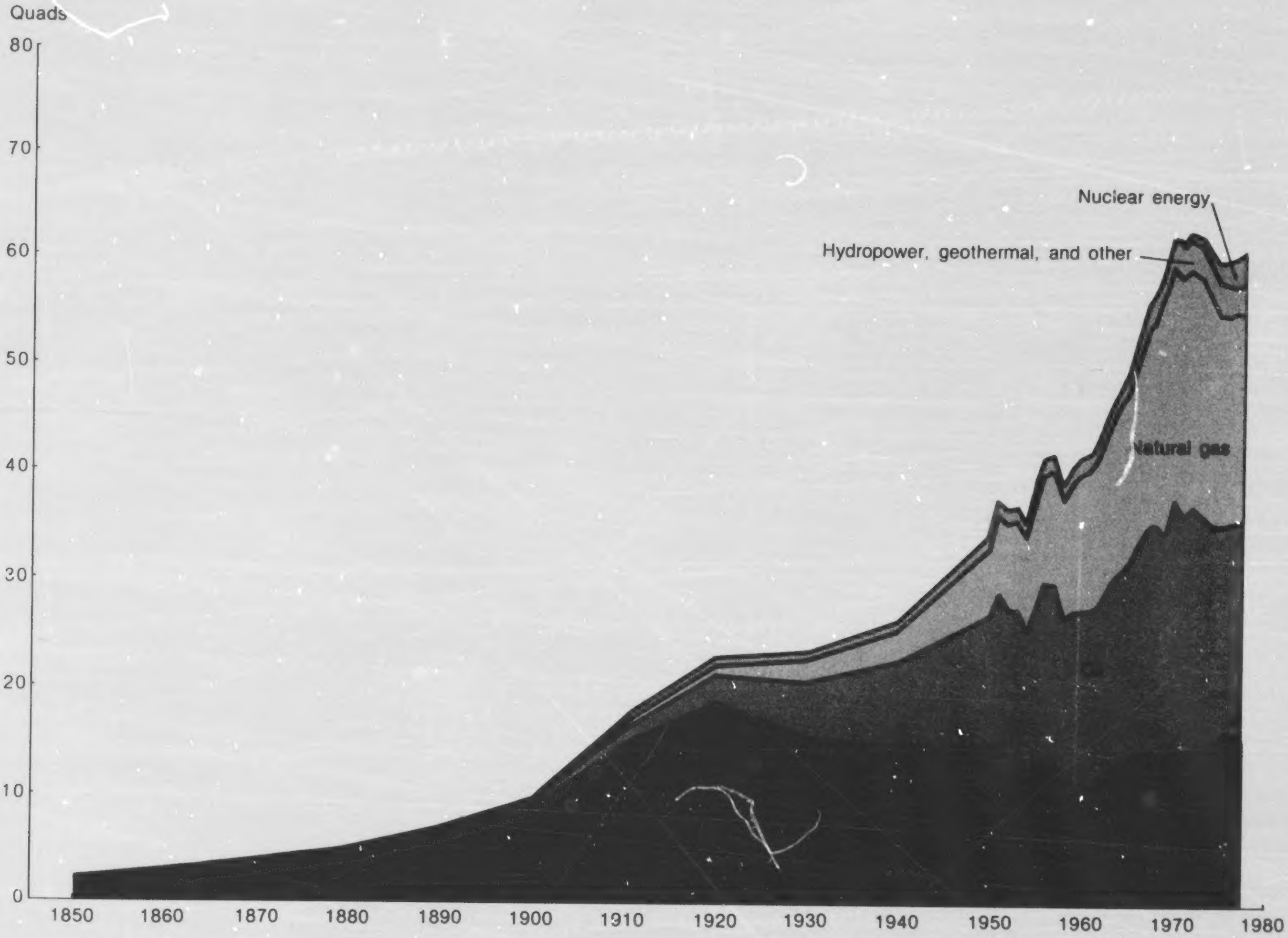


The most dramatic change in energy supply is the growing reliance on imports. As late as 1952, the United States was self-sufficient in energy. By 1973, nearly 17% of its energy needs were met with imports, primarily oil. Oil imports declined in 1974 and 1975 but rose in 1977 to their highest levels.

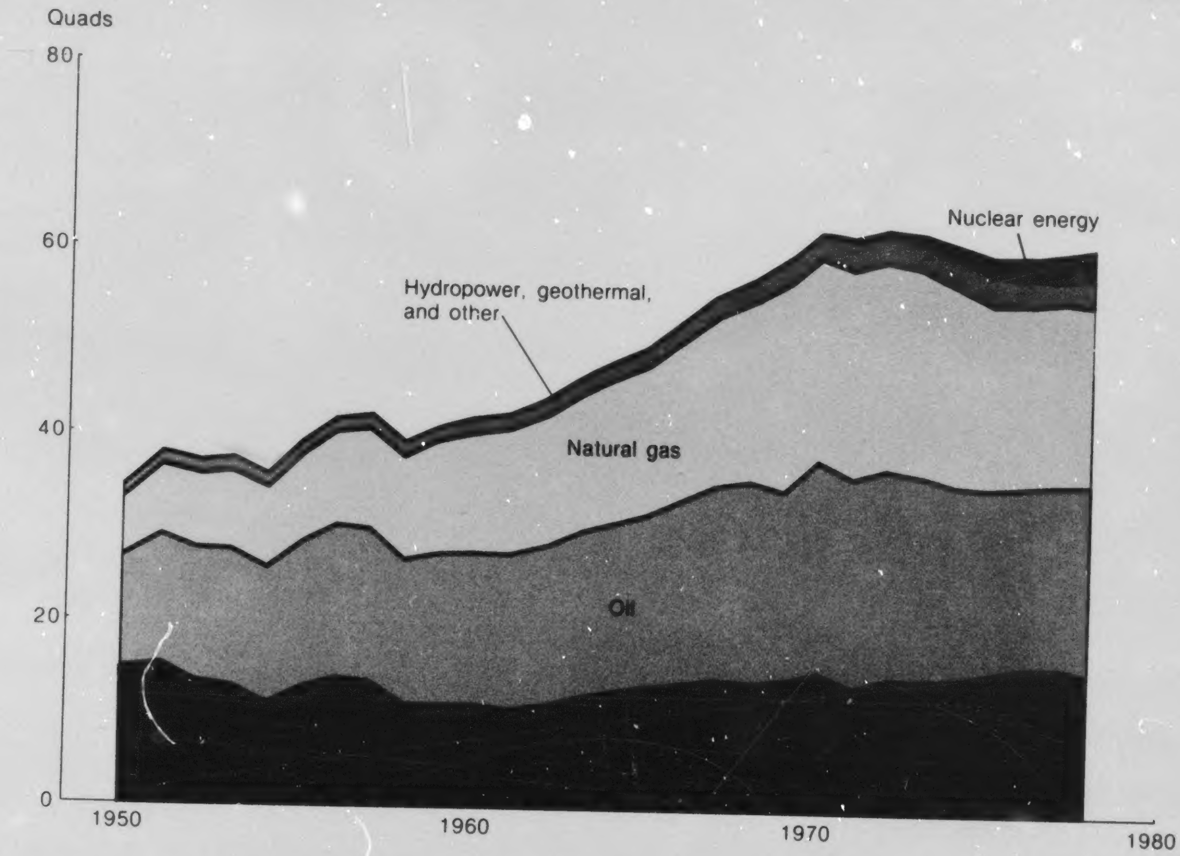
☐ Net trade is equal to exports minus imports.

9-4
Energy production, by fuel type, 1850–1978

The bulk of U.S. energy still comes from domestic sources. Over the years, the basic fuel has moved from wood to coal to crude oil and then to natural gas. With each change, the fuel became more efficient and burned more cleanly.


Quads
80
70
60
50
40
30
20
10
0
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
Nuclear energy
Hydropower, geothermal, and other
Natural gas

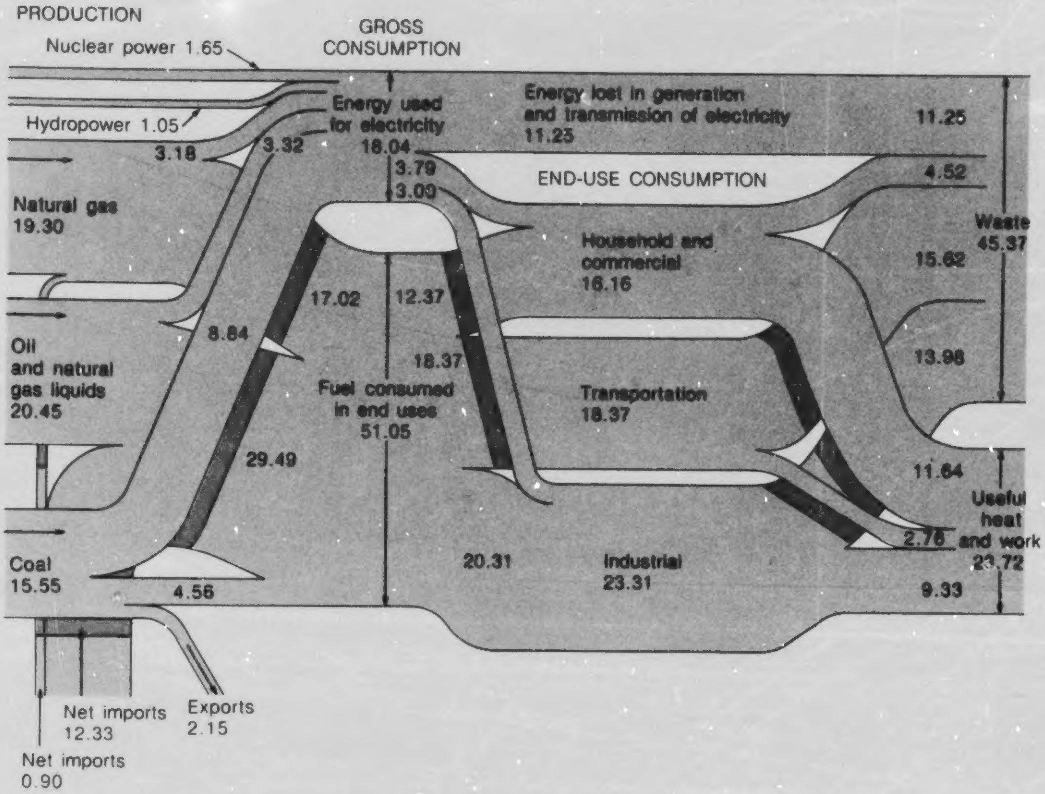
9-5
Energy production, by fuel type, 1950–1978



From 1950 to 1972, production increased at an average rate of 2.8% per year—not enough to meet the demand. Production peaked in 1972 and has since leveled off to between 60 and 62 quads per year.

Two important changes in production have taken place. First, the production and use of coal to generate electricity has increased rapidly since 1962. Second, the amount of energy produced from hydropower, nuclear, and geothermal resources has more than tripled since 1950—from 1.4 quads to 6.0 quads— although they accounted for only 10% of the energy produced in 1978.

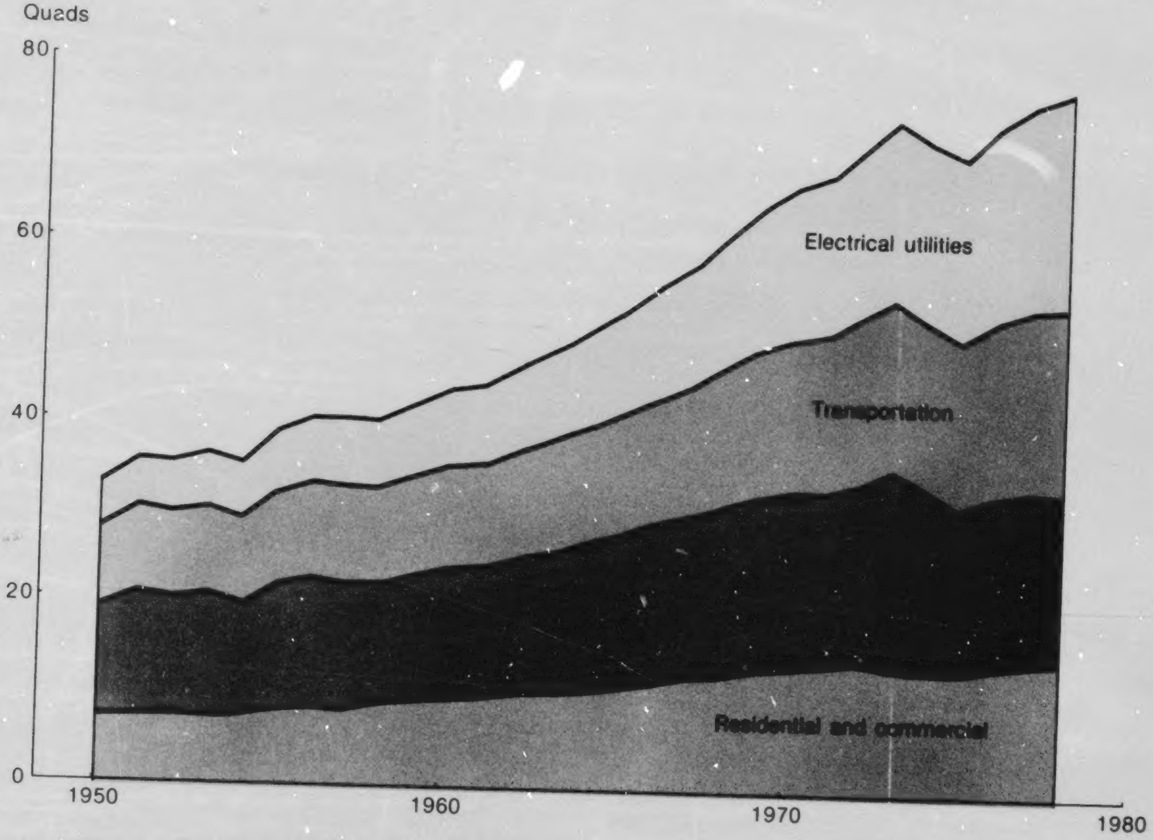
9-6
Energy flow in the U.S. economy, 1975


PRODUCTION
GROSS CONSUMPTION
Nuclear power 1.65
Hydropower 1.05
3.18
3.32
Energy used for electricity 18.04
Energy lost in generation and transmission of electricity 11.25
11.25
3.79
3.09
END-USE CONSUMPTION
4.52
Natural gas 19.30
Household and commercial 16.16
Waste 45.37
15.62
17.02
12.37
8.84
Oil and natural gas liquids 20.45
18.37
Fuel consumed in end uses 51.05
Transportation 18.37
13.98
29.49
11.64
Useful heat and work 23.72
2.76
Coal 15.55
20.31
Industrial 23.31
4.56
9.33
Net imports 12.33
Exports 2.15
Net imports 0.90

Energy from coal, oil, natural gas, hydropower, and nuclear power is either used to generate electricity or consumed directly in vehicles, in buildings, and by industry. In the process, nearly twice as much energy is lost as waste as is available for useful heat and work.

311

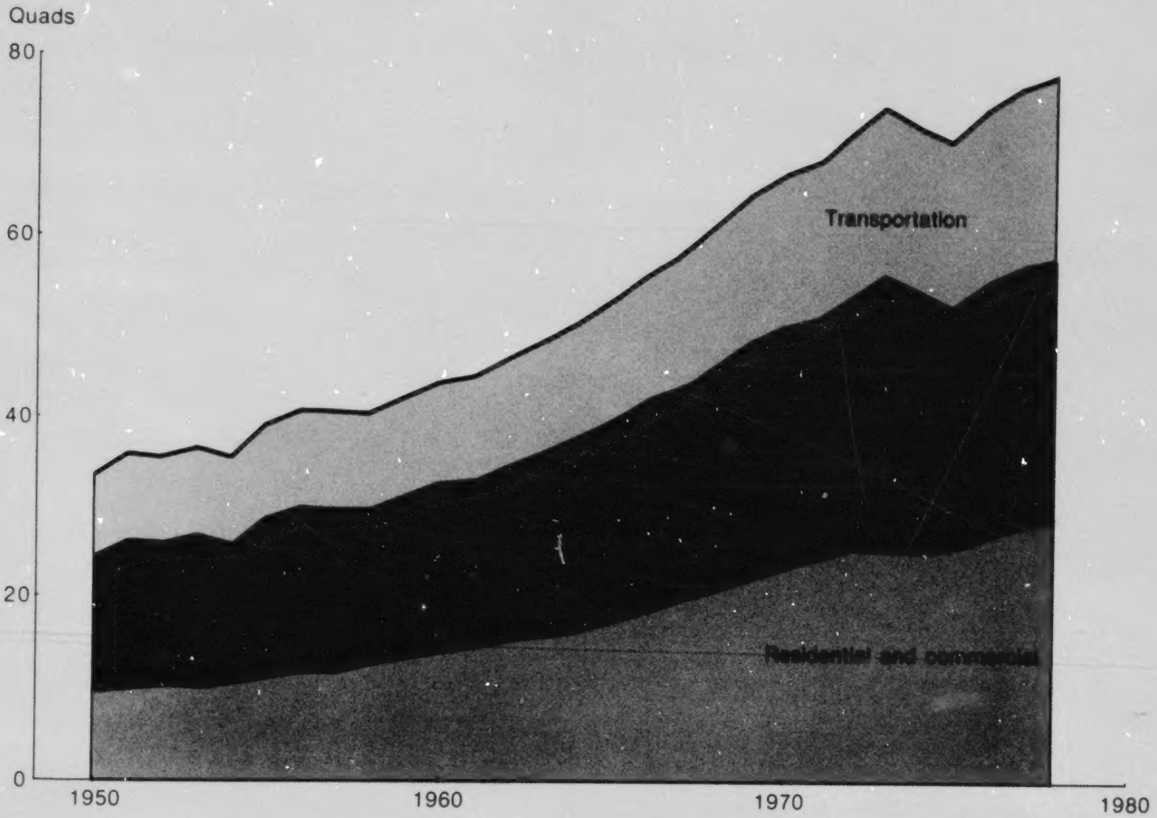
9-7
Energy consumption, by sector, 1950–1978



The use of energy to generate electricity has grown rapidly since 1950, when the electric utility sector consumed less than any other sector. It now consumes the most.

9-8

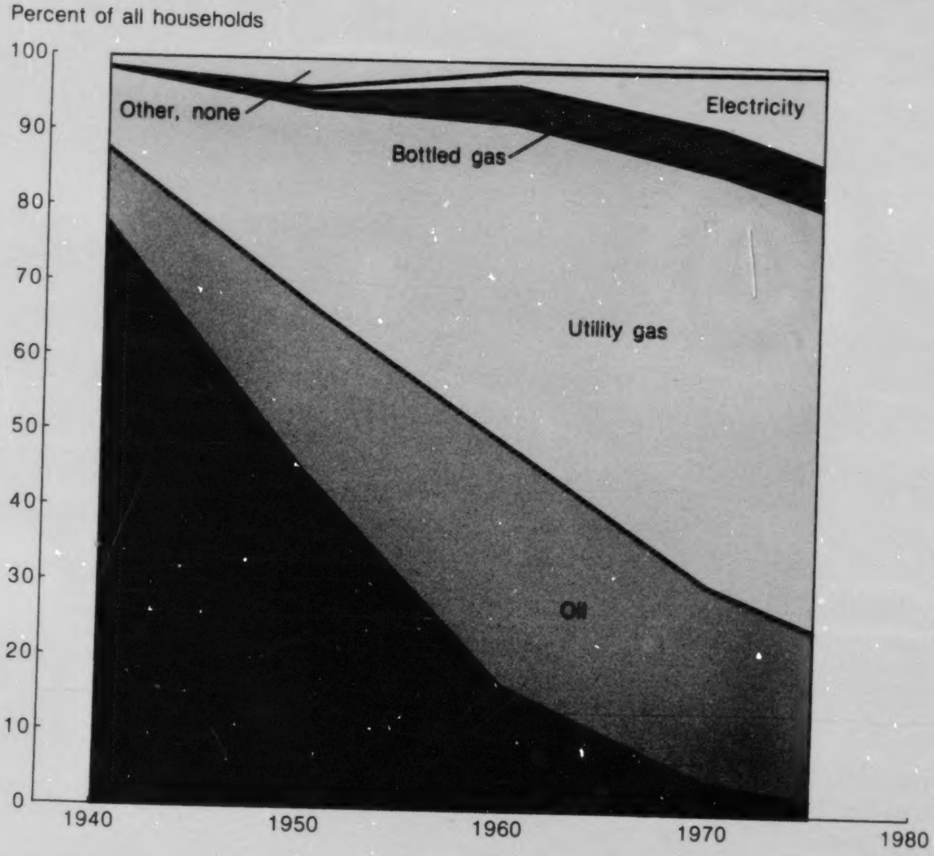
Energy consumption, by end use, 1950-1978



When electricity is allocated by end use, the 78 quads of energy consumed in 1978 look like this: households and commercial establishments used 29 quads, industries used 28, and transportation used 21.

9-9

Residential heating, by fuel type, 1940–1975

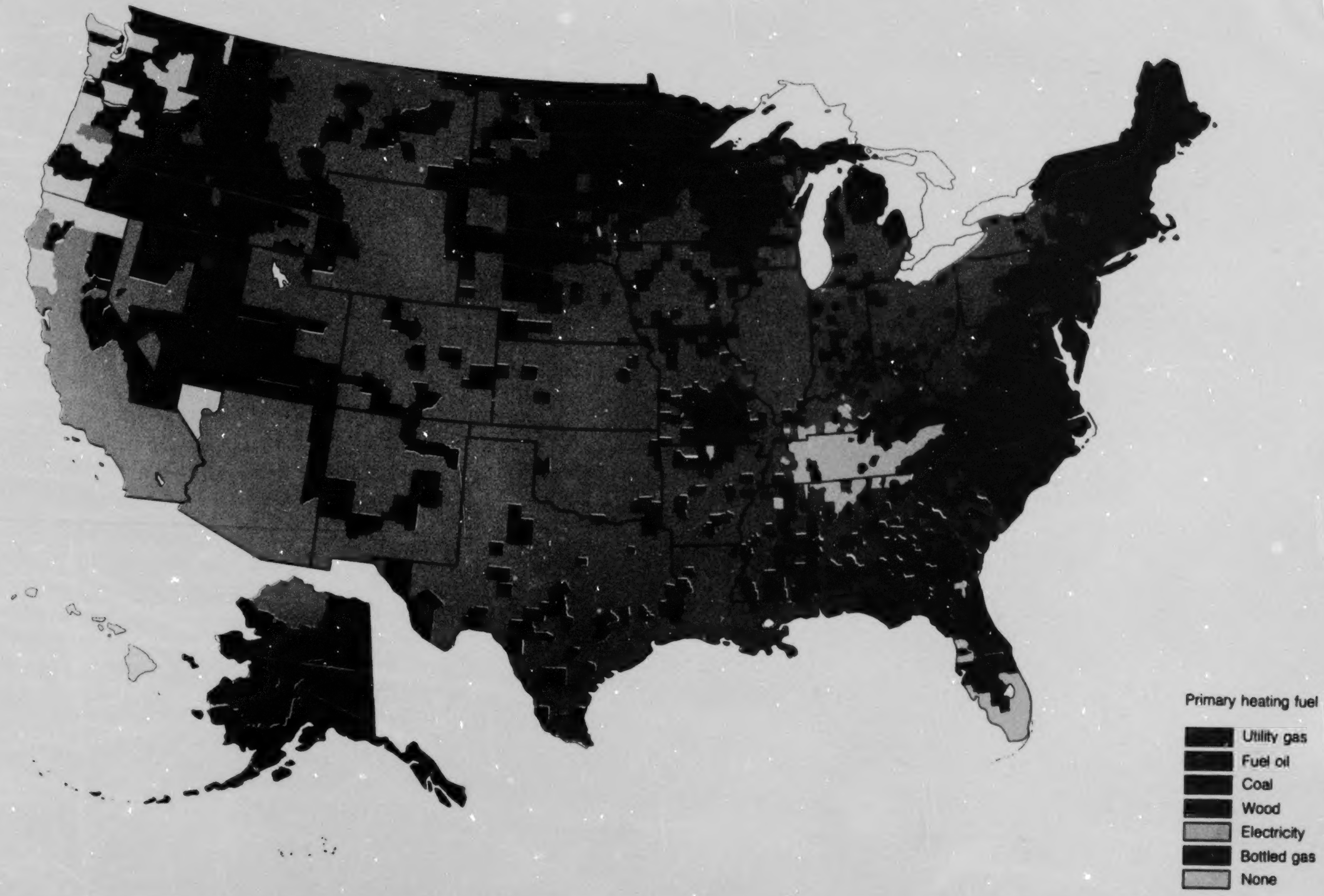


Space heating is the single most important use of energy in the home. In 1940, more than three of four homes were heated with coal or wood. By 1975, gas was used in six of ten households.

9-10

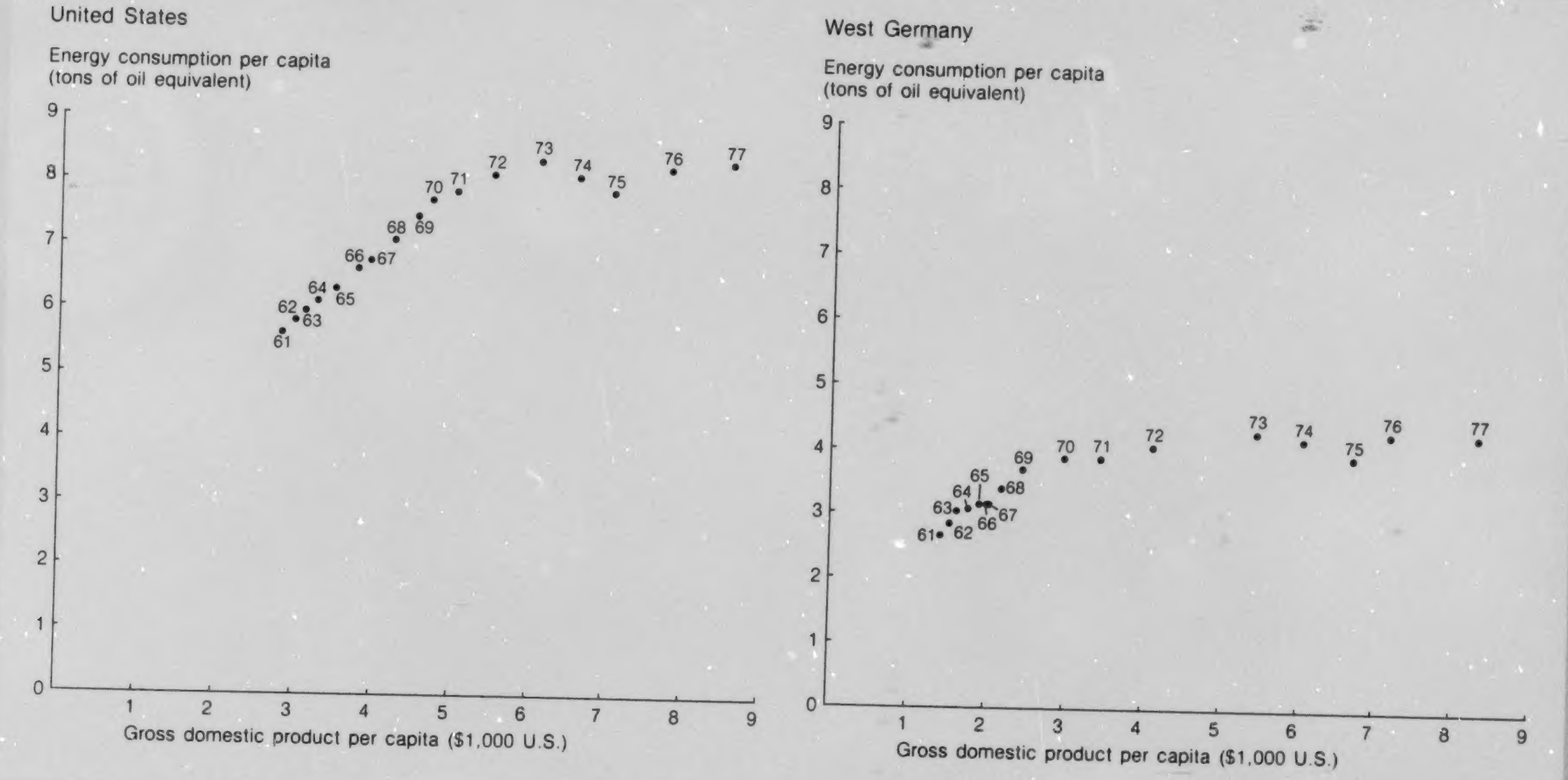
Residential heating, by fuel type and county, 1970

Coal and wood almost disappeared as primary fuels for home heating, while the use of electricity has grown rapidly and has become the dominant fuel in three regions of the country.


Primary heating fuel
Utility gas
Fuel oil
Coal
Wood
Electricity
Bottled gas
None

9-11

Per capita energy consumption and gross domestic product for four nations, 1961-1977

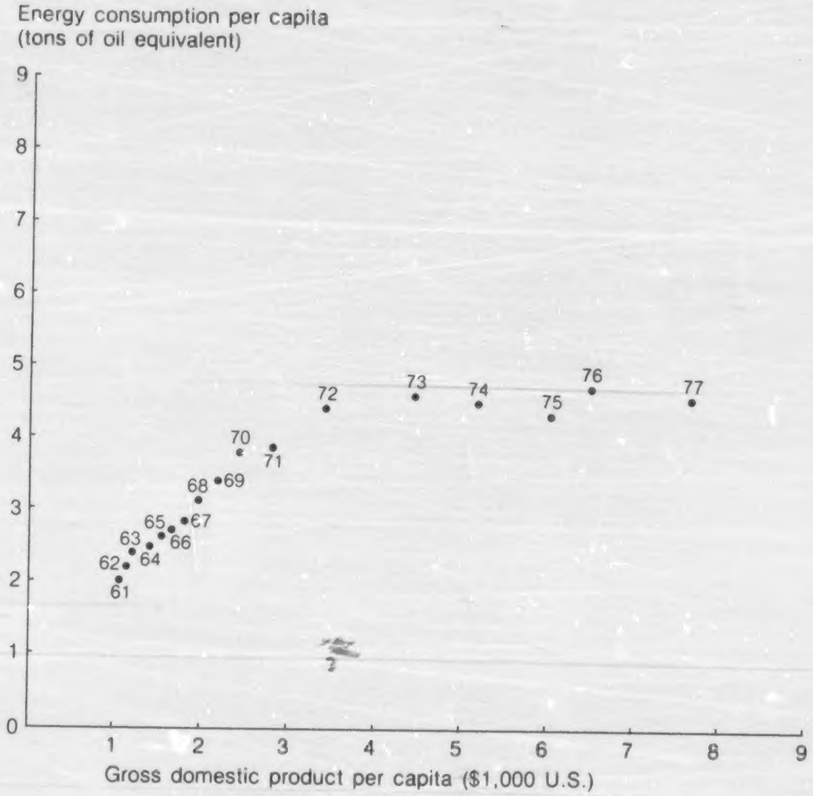


How energy consumption in the United States compares with that of other technologically advanced countries may be measured by the use of energy relative to the gross domestic product per capita.

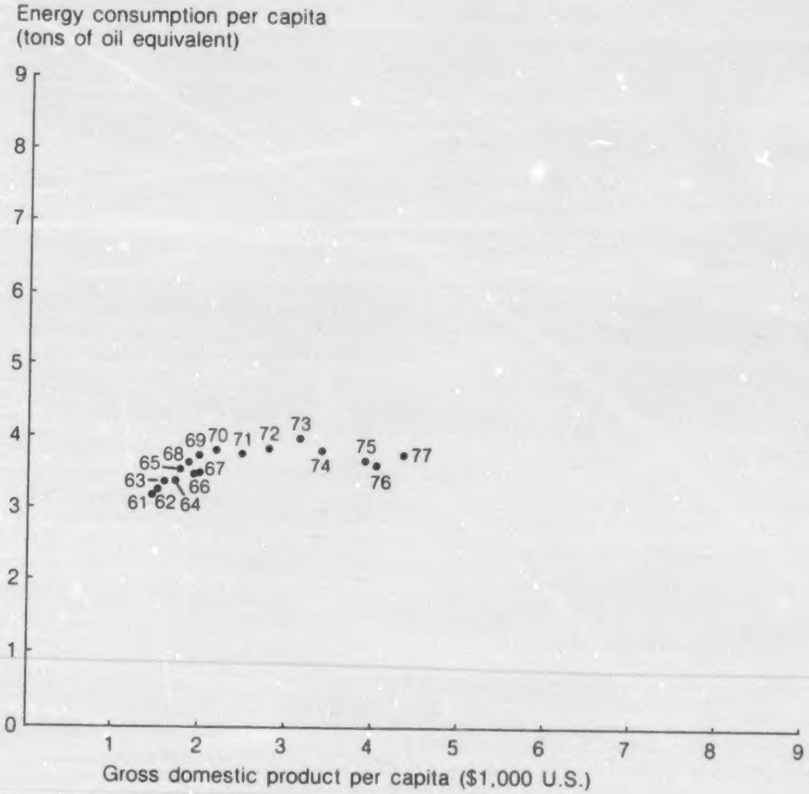
By this measure, the United States is a high energy consumer. In 1977, West Germany used more than 4 tons of oil equivalent per person and the United States more than 8 tons to achieve an economic level of about $8,400 in goods and services per year.

☐ Gross domestic product (GDP) measures a nation's domestic economic activity.

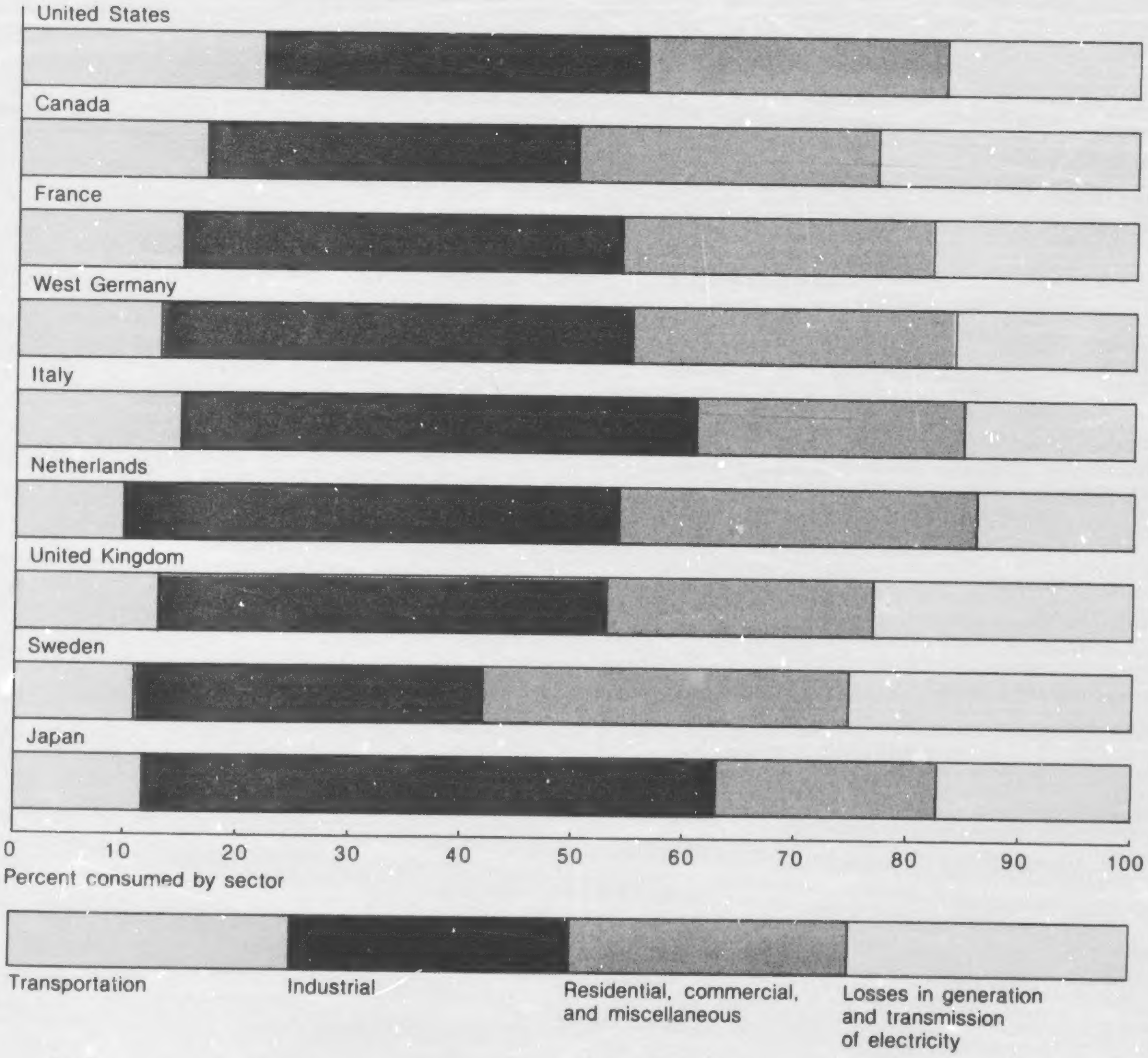
Netherlands



United Kingdom



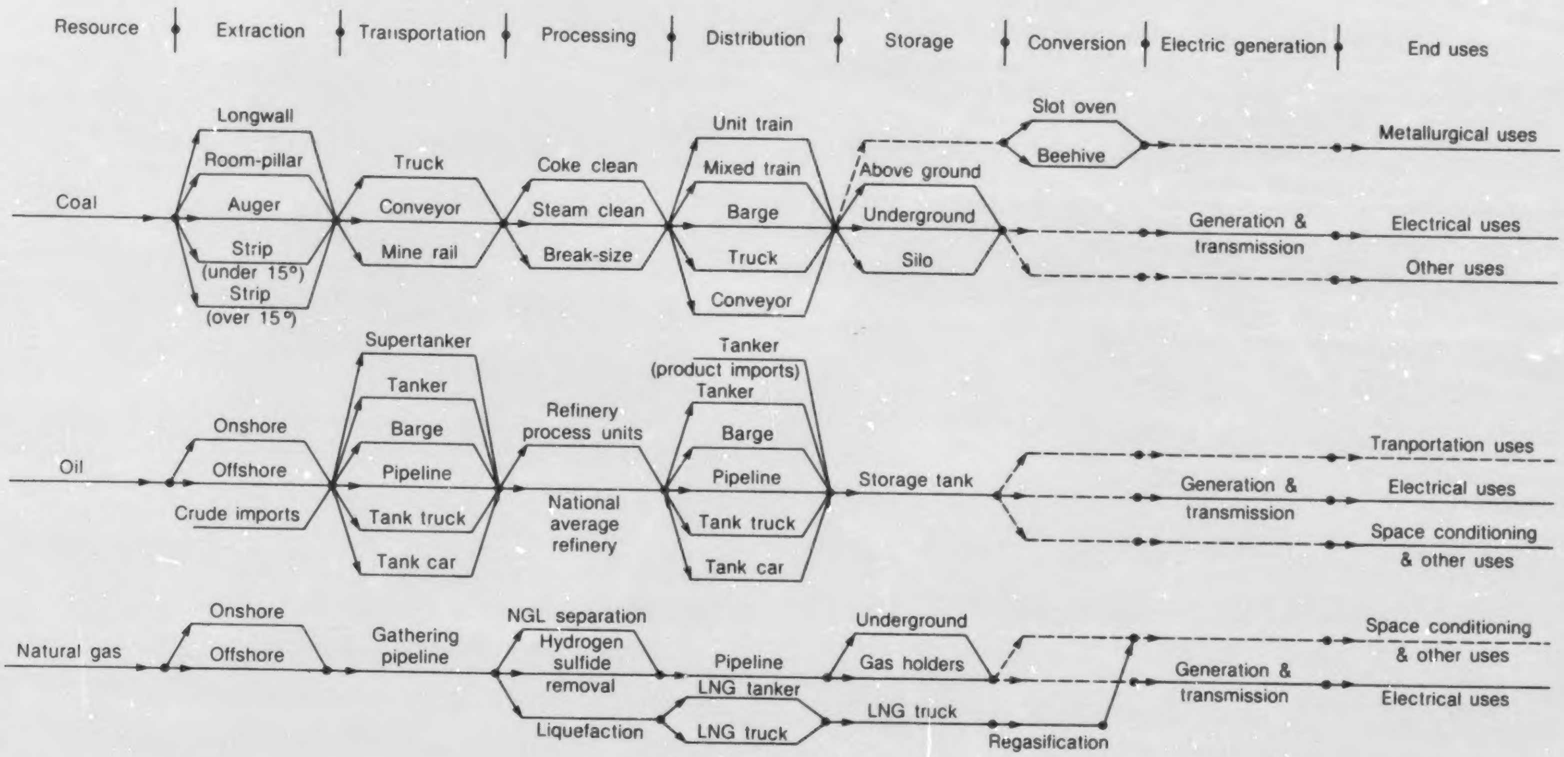
9-12
Energy consumed by sector for nine nations, 1972



The United States and Canada use relatively more energy for transportation than other industrial countries. The primary reason is that Japan and the European countries have fewer and smaller cars—which use less fuel and are driven fewer miles. Although the United States uses relatively more energy for transportation than the Netherlands, for example, the Netherlands uses relatively more than the United States in the industrial and residential sectors.

9-13

Energy supply systems for fossil fuels

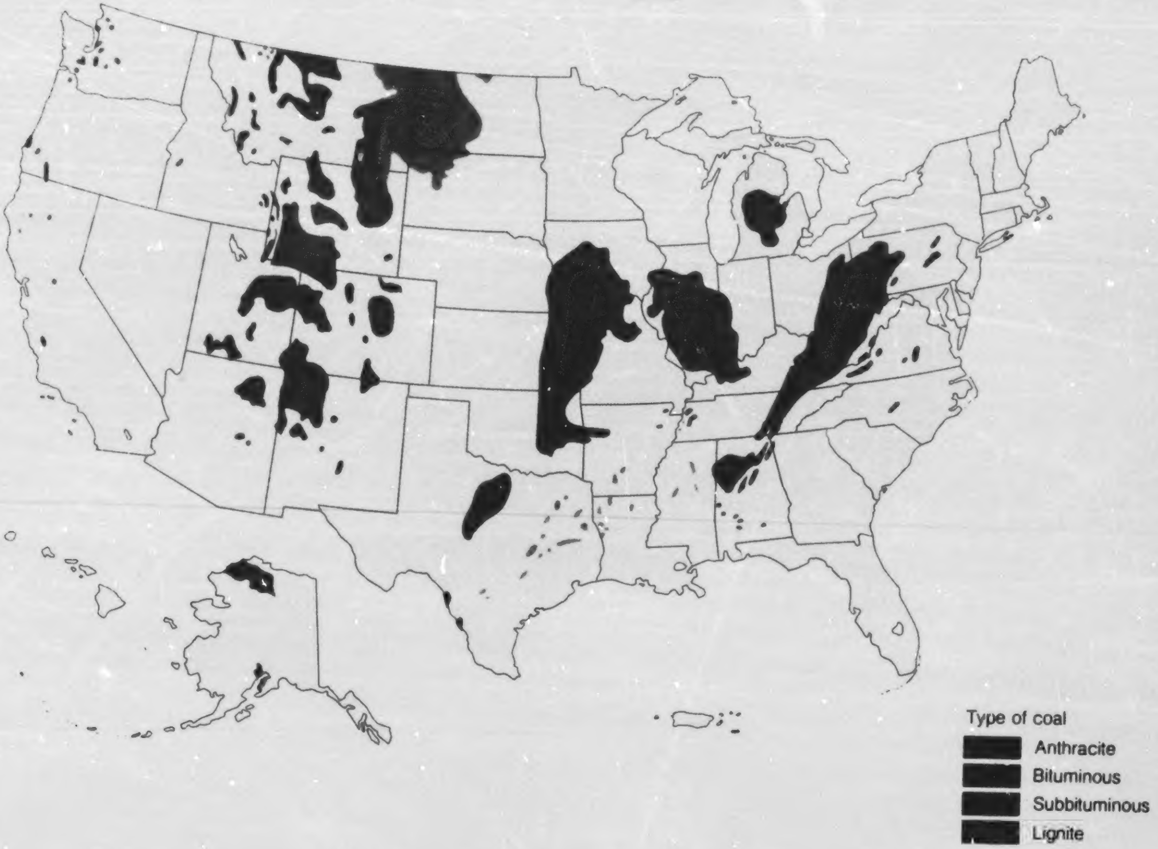

Resource
Extraction
Transportation
Processing
Distribution
Storage
Conversion
Electric generation
End uses
Coal
Longwall
Room-pillar
Auger
Strip (under 15°)
Strip (over 15°)
Truck
Conveyor
Mine rail
Coke clean
Steam clean
Break-size
Unit train
Mixed train
Barge
Truck
Conveyor
Above ground
Underground
Silo
Slot oven
Beehive
Generation & transmission
Metallurgical uses
Electrical uses
Other uses
Oil
Onshore
Offshore
Crude imports
Supertanker
Tanker
Barge
Pipeline
Tank truck
Tank car
Refinery process units
National average refinery
Tanker (product imports)
Tanker
Barge
Pipeline
Tank truck
Tank car
Storage tank
Generation & transmission
Tranportation uses
Electrical uses
Space conditioning & other uses
Natural gas
Onshore
Offshore
Gathering pipeline
NGL separation
Hydrogen sulfide removal
Liquefaction
Pipeline
LNG tanker
LNG truck
Underground
Gas holders
LNG truck
Regasification
Generation & transmission
Space conditioning & other uses
Electrical uses

The environment is affected at all steps of energy development, from exploration, harvesting or mining, concentration, refining, conversion, transportation, storage, and marketing to end use.

Some impacts are additions to the environment—sulfur dioxide and particulates released in the combustion of coal, spilled oil, and radiation from nuclear fission, for example. Each addition may not create stress on the environment, but cumulative effects may be serious.

Energy growth is limited by environmental and socioeconomic effects as well as by availability of resources.

9-14
Coal fields, 1970s

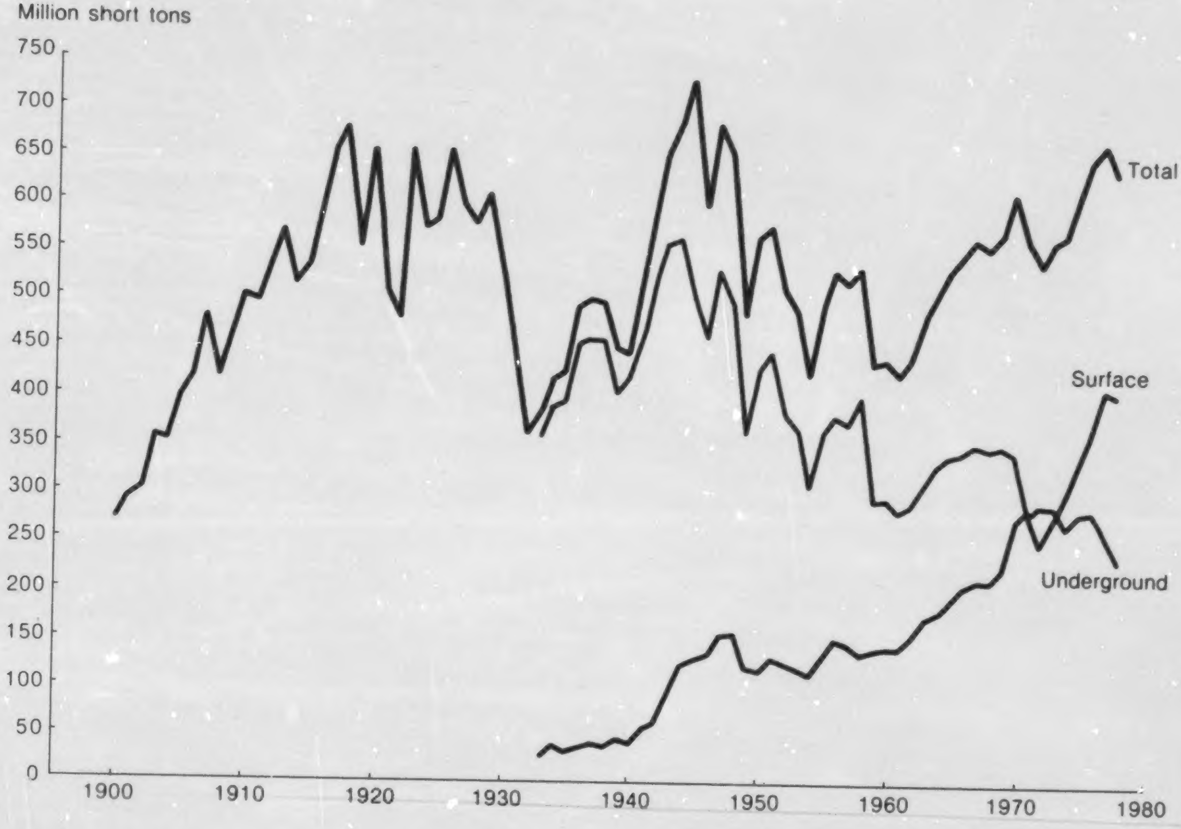


Coal is the Nation's most abundant fossil fuel, making up 95% of fossil fuel reserves. Coal is also one of the most environmentally damaging fuels, emitting fine particulates, hydrocarbons, nitrogen and sulfur oxides, and trace metals when it burns without control.

Anthracite is the hardest and has the highest heat content of the coals. Reserves of bituminous coal are the most abundant. Lignite and subbituminous coals are lowest in sulfur content.

Coal reserves in the East are generally deeper than those in the West, where they can be surface mined. In the West, reclamation of disturbed land is made difficult by the shortage of water.

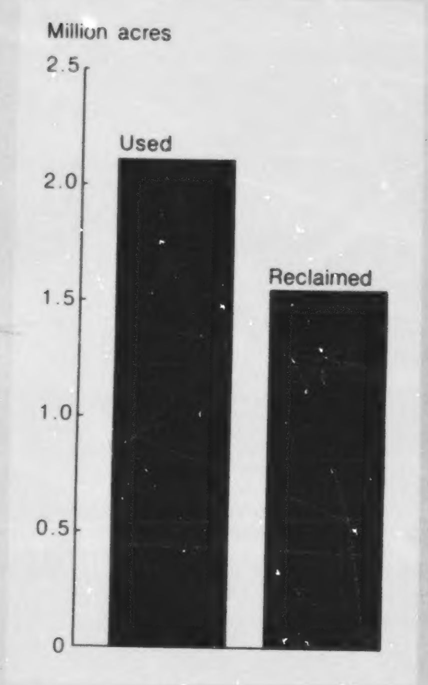
9-15
Coal production, 1900–1978



In 1977, coal production reached 665 million tons, equal to the peak during World War II. Production fell in 1978 because of lower demand and an extended coal strike. Surface mining now accounts for almost two-thirds of all coal mined. In 1978, about three-fourths of all coal mined was used to generate electricity.

USC

9-16
Land disturbed and reclaimed by the coal mining industry, 1930–1978



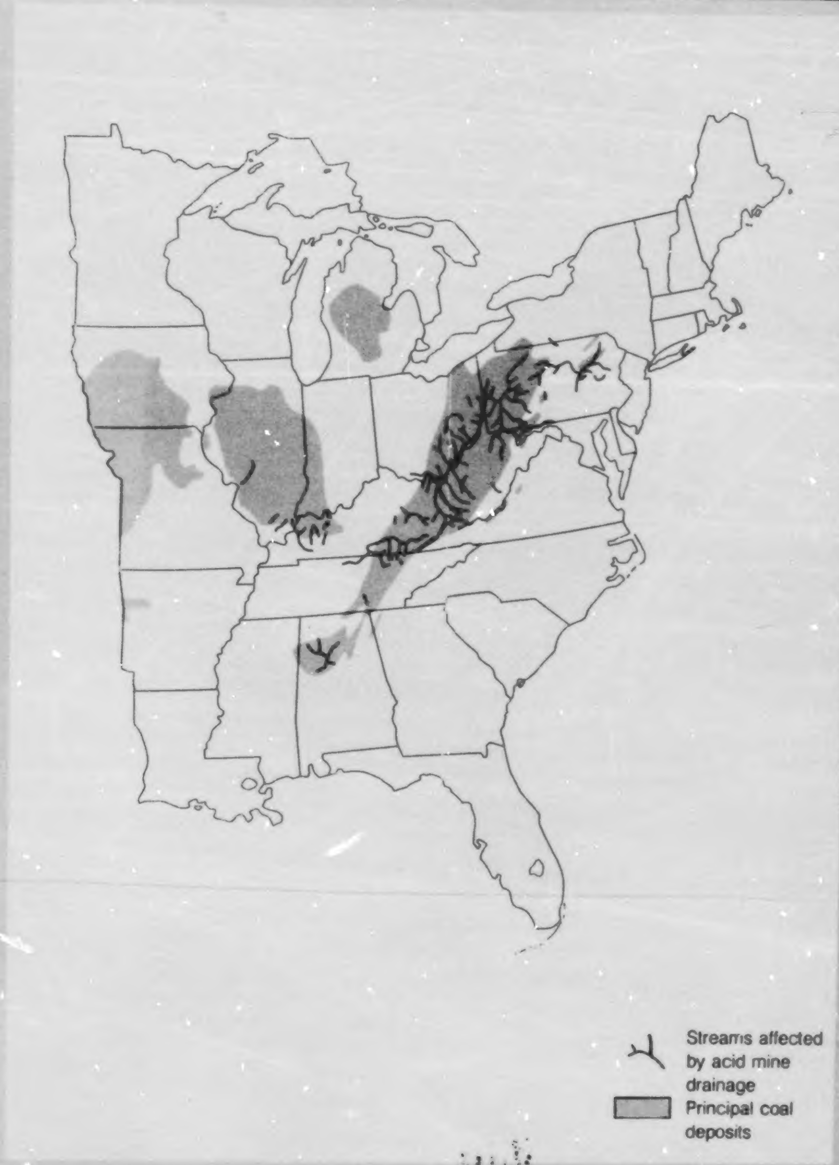
From 1930 to 1978, roughly 2 million acres (an area two-thirds the size of Connecticut) were disturbed by coal mining operations. About 65% of this area has been reclaimed by mine operators—that is, initial revegetation was completed.

The Surface Mining Control and Reclamation Act of 1977 requires the States to set land reclamation standards in order to restore the land to its original contour wherever practical, to stablize erosion, to avoid disturbing the hydrological balance, and to restore vegetation.

9-17
Streams affected by acid mine drainage, 1970s

Not all the impacts of mining are so direct as land disturbance. Acid mine drainage seriously pollutes streams, especially in Appalachia and the Ohio River basin. Sulfuric acid and iron compounds form when water and air react with sulfur-bearing minerals in mines or refuse piles. Acidic water washed out of mines can alter the composition of drainage systems.

An estimated 10,500 miles of streams have been affected by acid mine drainage. Of them, about 5,700 miles, primarily in Pennsylvania, Maryland, West Virginia, Ohio, and Tennessee, are continually polluted. Acidic waters destroy fish larvae and corrode piers, bridges, and industrial equipment.

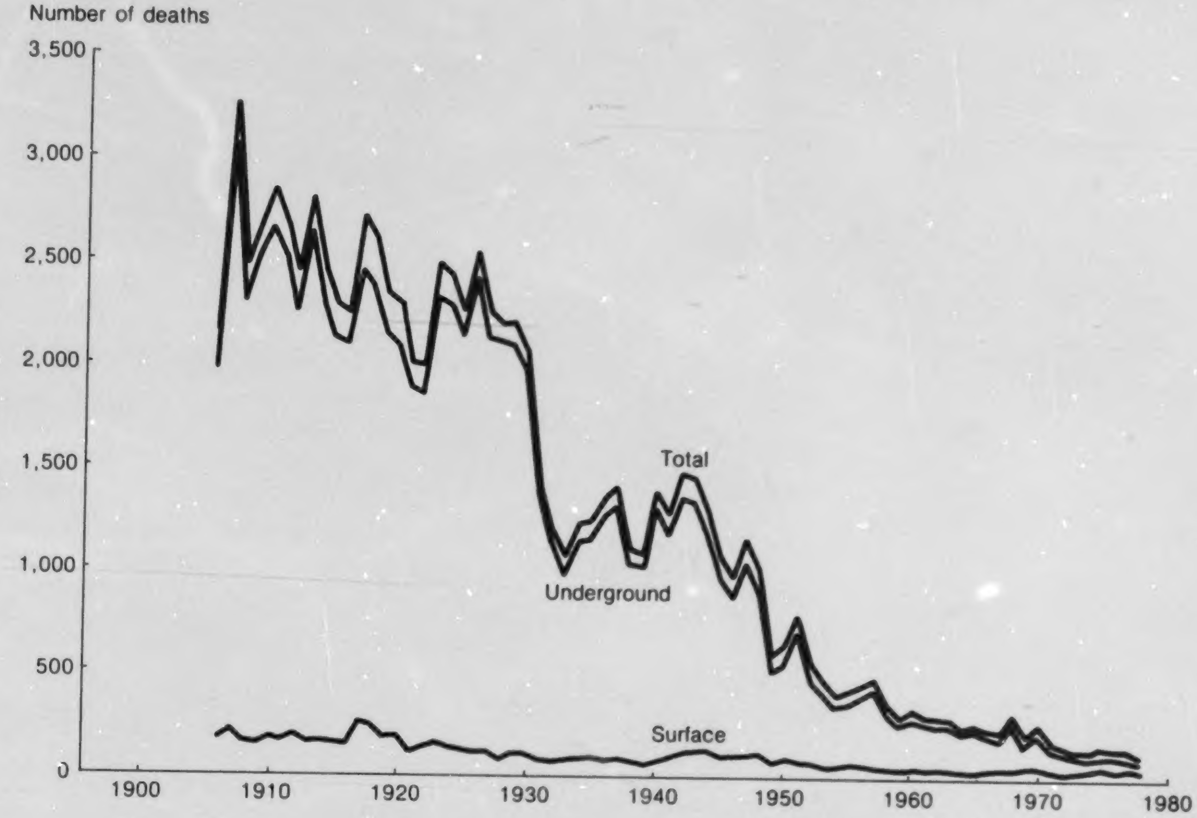


9-18

Coal mine deaths from accidents, 1906–1978

Miners risk accidental injury and death and such diseases as pneumoconiosis (black lung), emphysema, and bronchitis, which affect thousands of workers, reducing their life expectancy and seriously disabling many. The number of deaths in coal mining operations has declined substantially since 1900. In 1978, the number of recorded deaths was 106, compared to more than 3,000 in 1907. Fewer miners, more and better safety precautions, and improved equipment have brought about the change.

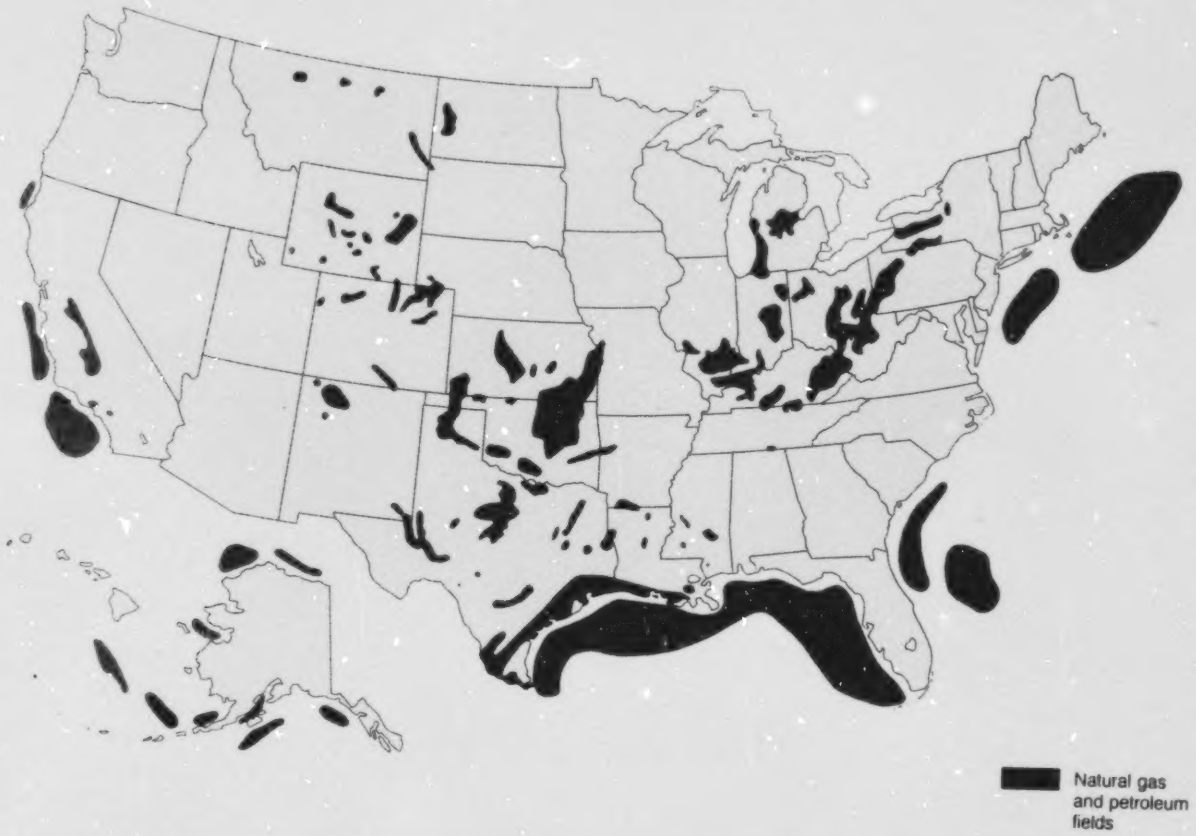
There are no summary data on cases of black lung disease resulting from years of exposure to mine conditions. But coal miner mortality from influenza, emphysema, asthma, tuberculosis, and all other respiratory diseases (including black lung) is greater than expected.



330

331

9-19
Natural gas and petroleum fields, 1970s



More natural gas and oil are consumed than any other fuel. Oil accounts for roughly half of all energy used and natural gas accounts for a fourth. Both are easy to transport and are generally relatively clean-burning fuels.

Oil and natural gas fields are located primarily in Texas, Oklahoma, and Louisiana and in the outer continental shelf of the Atlantic, Gulf, Pacific, and Alaskan coasts. In 1977, about 10% of oil production was in the outer continental shelf.

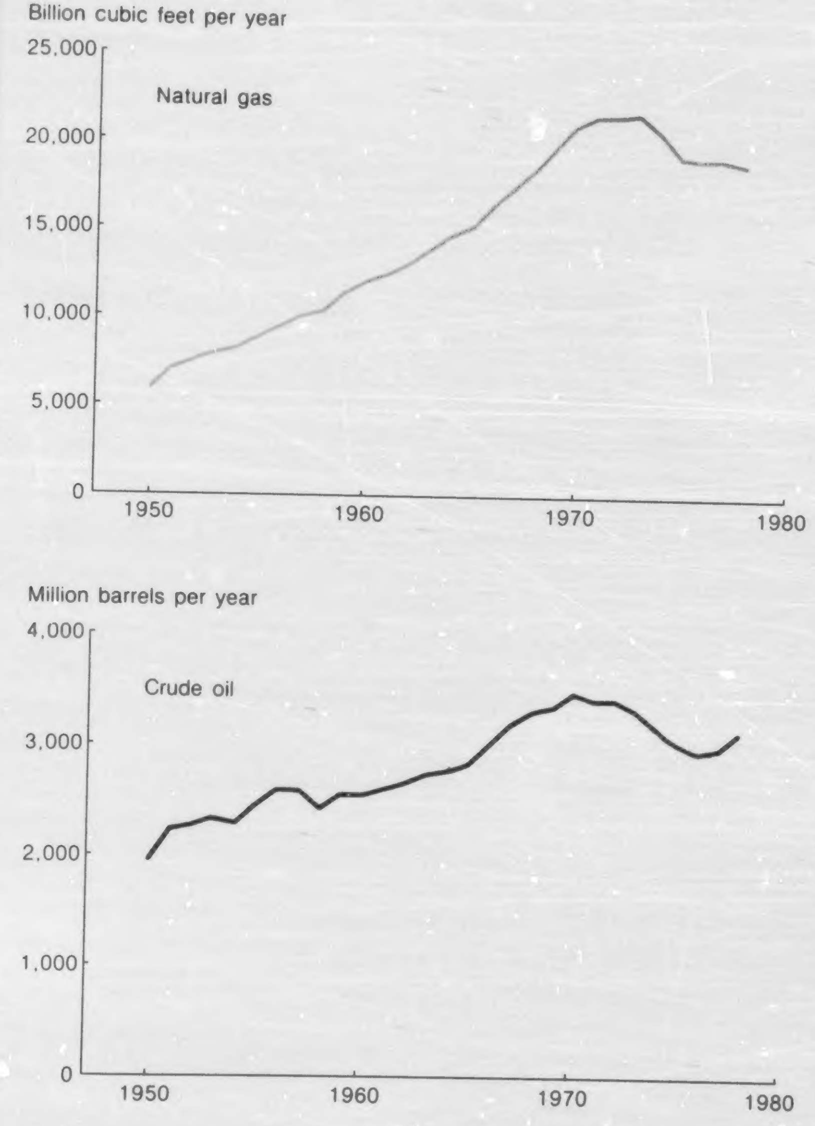
In 1977, 2.5 million acres in the outer continental shelf were offered for leasing. Of that, oil companies have leased 1.1 million acres. In a lease sale, the Federal Government sells into private ownership the right to explore, develop, and produce oil and gas. The buyer then explores for oil and gas. If any is found, the buyer pays a royalty based on the amount produced.

332

333

9-20

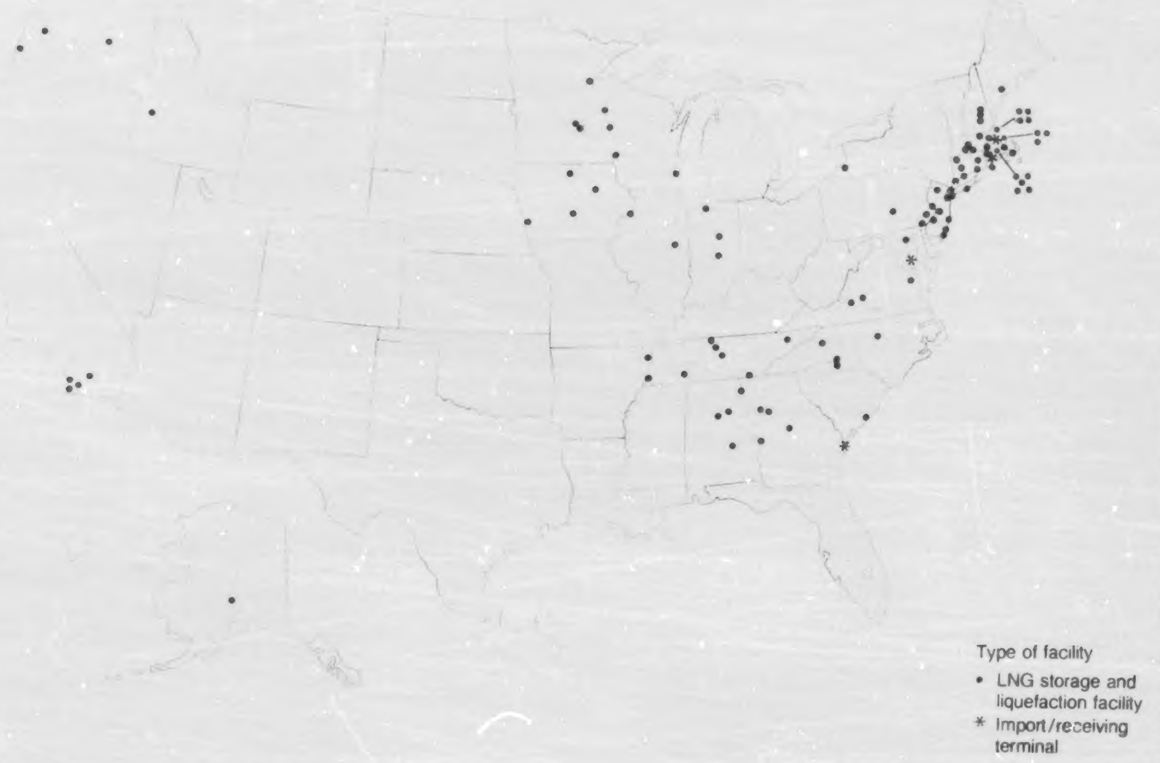
Natural gas and oil production, 1950–1978



Natural gas production reached a high point in 1973 at 21,730 billion cubic feet. In 1990, about 5% of domestic production will come from Alaska. In 1976, domestic production was 40% of the world total.

Production of oil peaked at 3.5 billion barrels in 1970. Of that, 16.4% was from offshore wells. Currently 15% of domestic production is Alaskan. In 1976, domestic production was 14% of the world total.

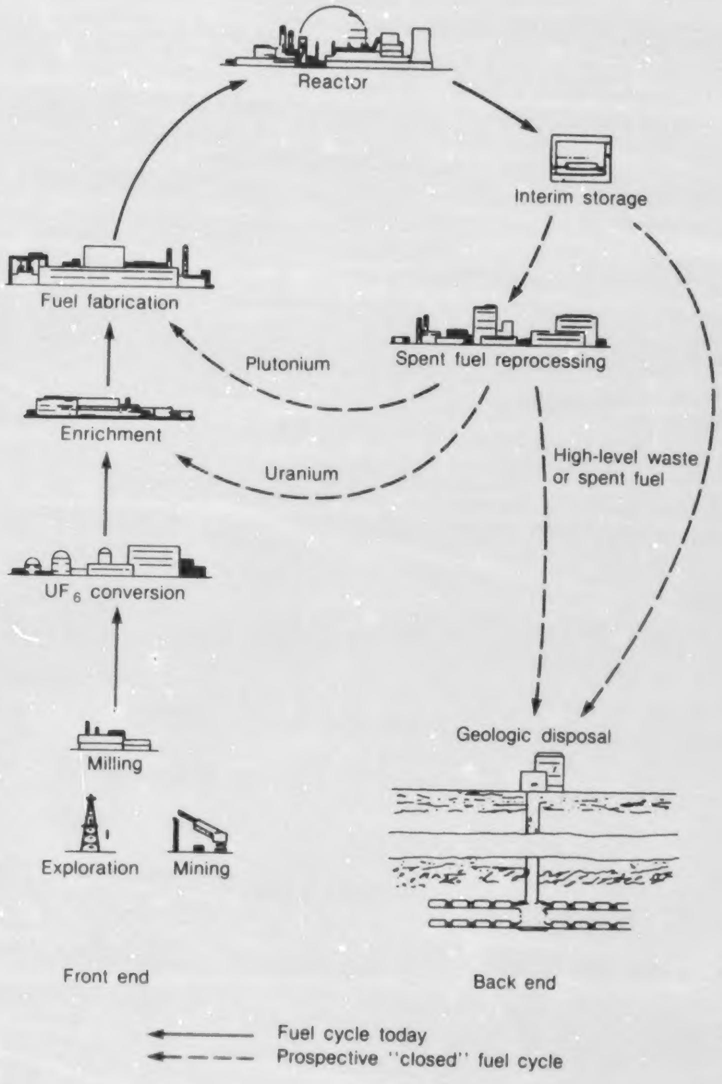
9-21
Liquefied natural gas facilities, 1980


Type of facility
• LNG storage and liquefaction facility
* Import/receiving terminal

In a supercooled state, natural gas becomes a liquid. Its volume is reduced by a factor of 600, and it can be transported in specially designed tankers. Four liquefied natural gas (LNG) receiving terminals are located in Massachusetts, Rhode Island, Maryland, and Georgia. From them, the imported gas is transported to storage and regasification facilities.

The main concern with LNG is safety. If a tank containing LNG were to rupture, the LNG would vaporize quickly, posing a threat of explosion or fire. The only major LNG accident in the United States occurred in Cleveland in 1944, killing 130 people.

9-22
Nuclear fuel cycle

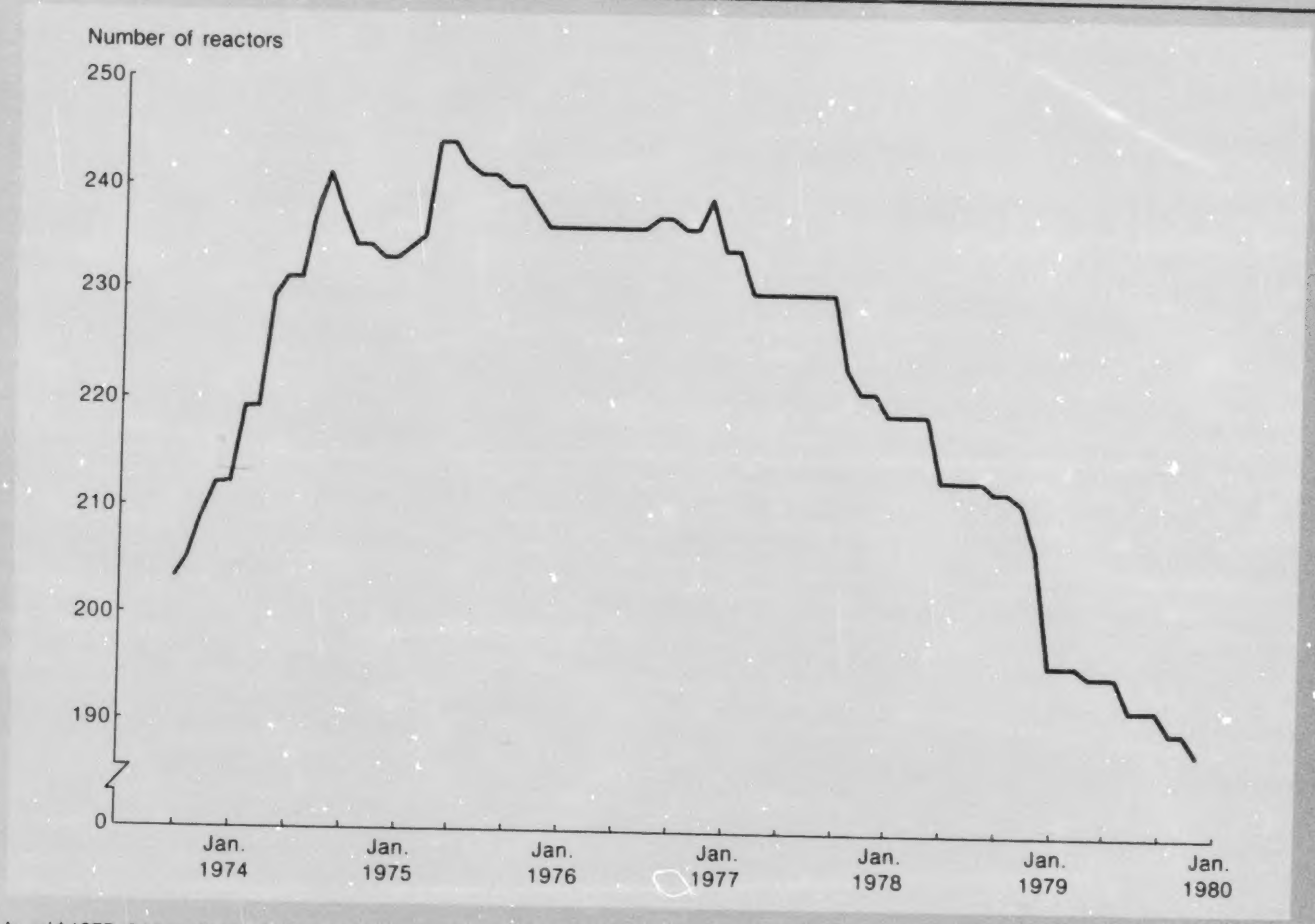

Reactor
Interim storage
Fuel fabrication
Spent fuel reprocessing
Plutonium
Enrichment
Uranium
High-level waste or spent fuel
UF$_6$ conversion
Geologic disposal
Milling
Exploration
Mining
Front end
Back end
Fuel cycle today
Prospective "closed" fuel cycle

Nuclear power was first used commercially in 1957, when a nuclear power plant in Shippingport, Pennsylvania, began to produce electricity. Nuclear power is based on the fissioning or splitting of the nuclei of plutonium or uranium-235 into lighter elements, releasing energy in the process. In a fission nuclear reactor, a chain reaction is controlled to produce heat. This heat then produces steam at high pressure, which drives a steam turbine, turning an electric generator.

A major environmental problem associated with nuclear power generation is the release of radiation which may occur at all stages of the fuel cycle. Release may occur through mishandling of materials, accidents, or sabotage. Another problem is waste heat emitted into waterways and the atmosphere. Waste heat occurs because power plants use only a third of the thermal energy they produce.

9-23

Nuclear reactors built, being built or planned, September 1973–December 1979

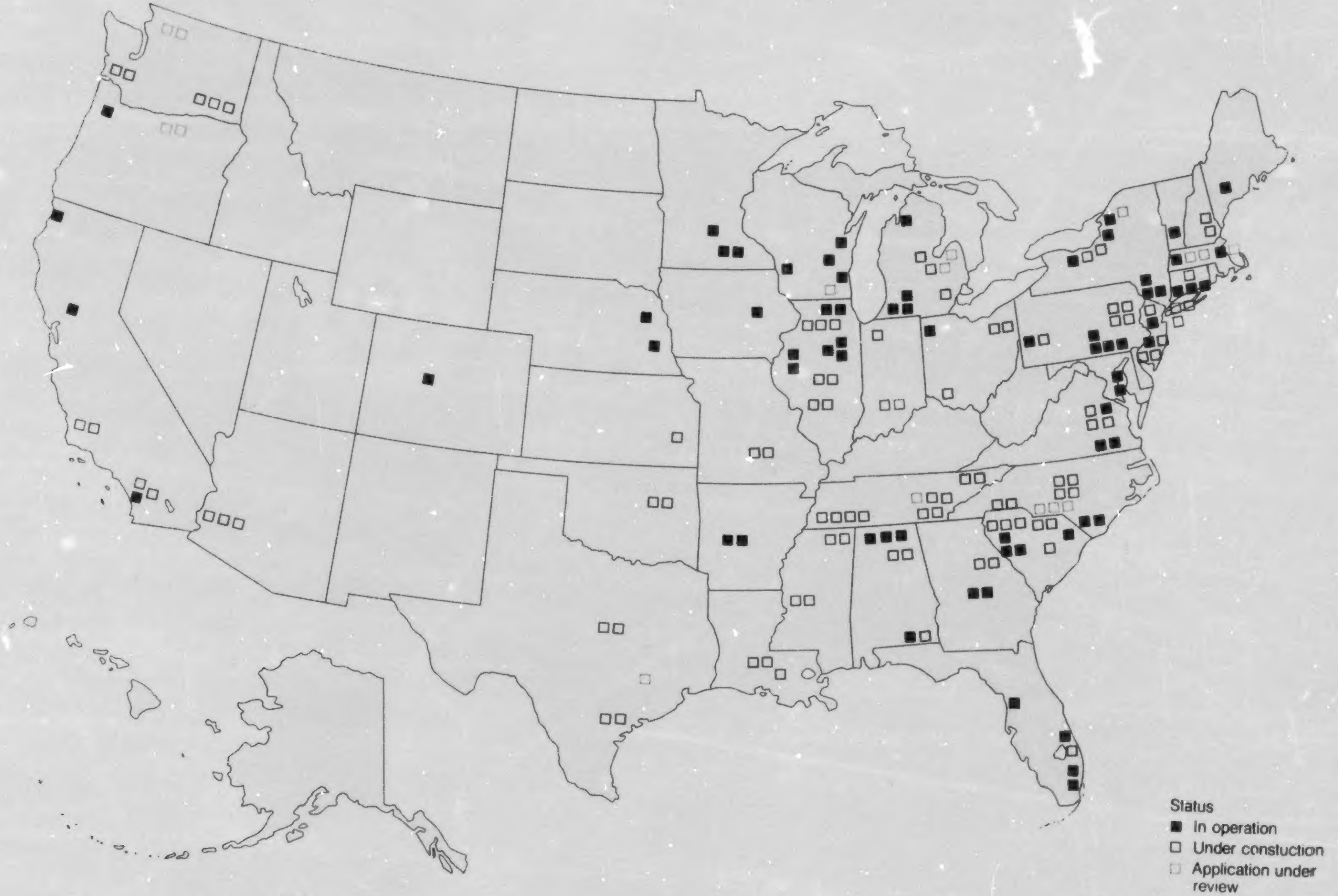


In mid-1975, 244 nuclear reactors had been built, were being built, or were planned. By the end of 1979, the number had dropped to 188. The 56 cancellations were the result of reduced estimated demand for electric power, financial problems, or safety concerns.

9-24

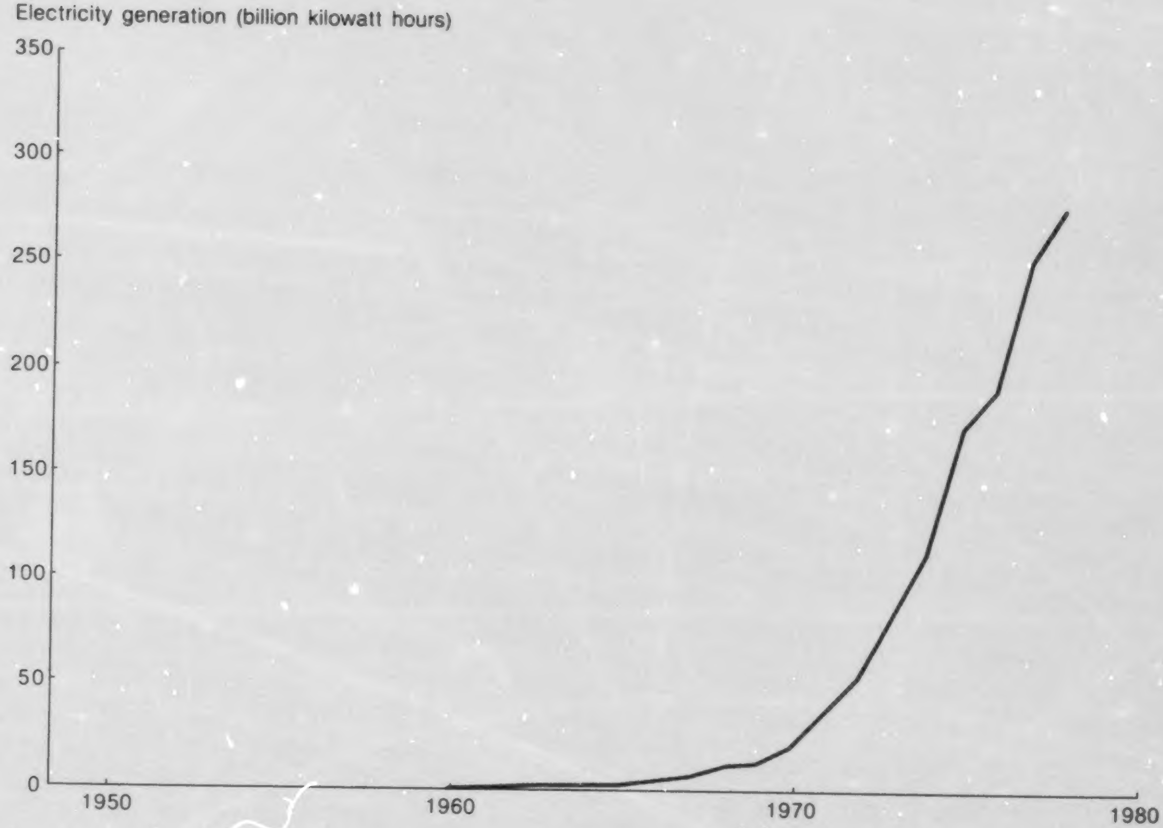
Nuclear reactors, December 1979

Twenty years ago, only 2 nuclear power reactors were in operation. In 1970, there were 16, and at the end of 1979, there were 70.


Status
■ In operation
□ Under constuction
▫ Application under review

Map excludes 4 nuclear reactors ordered and 2 publicly announced.

9-25
Nuclear power generation, 1957–1979



Nuclear power reactors now produce more than 255 billion kilowatt hours of electricity each year—about 11.4% of the total generated in 1978.

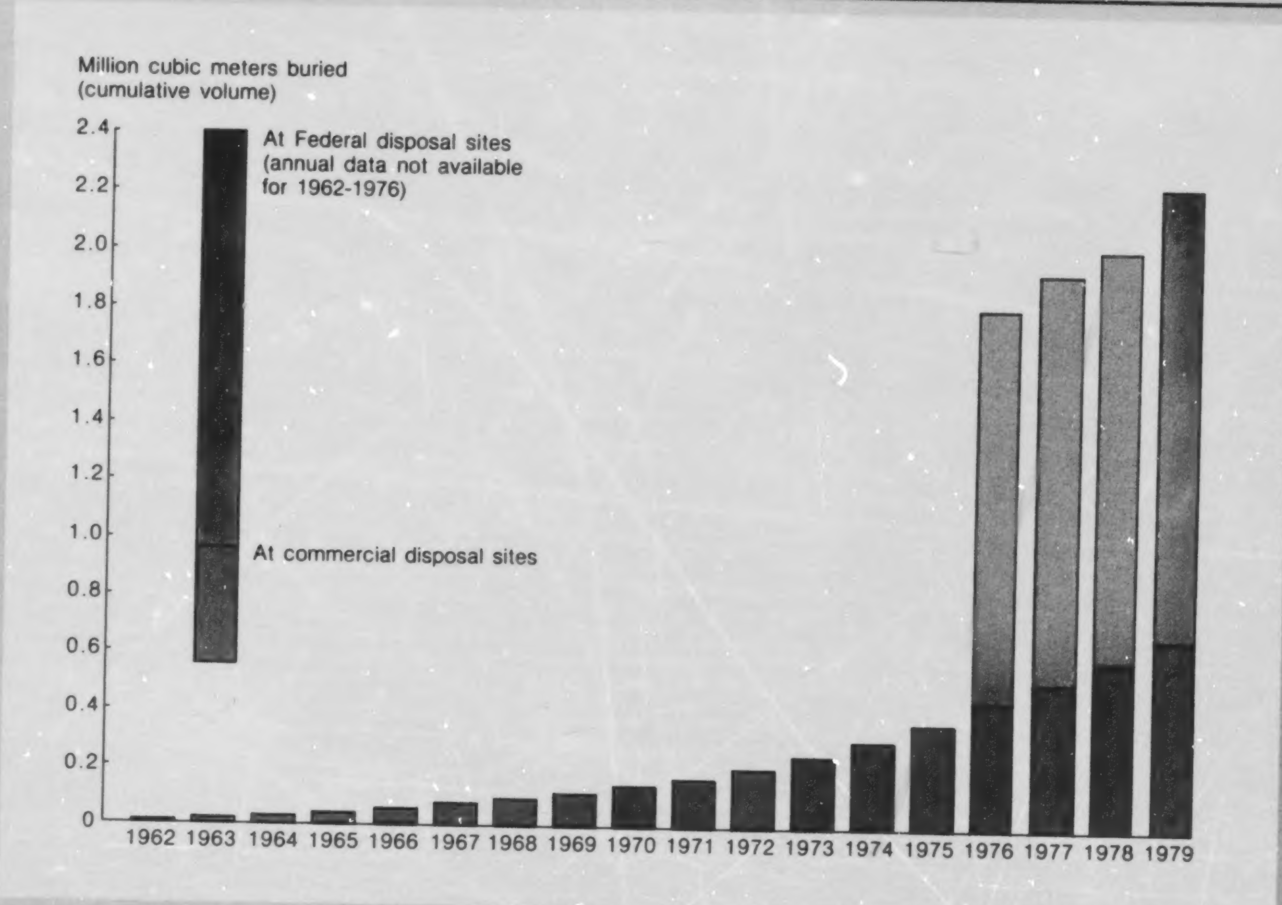
9-26

Low level radioactive wastes disposed of, 1962-1979

Wastes are generated at all stages in the nuclear cycle. Low-level wastes are the tailings from uranium mining and milling and the materials and equipment used in the nuclear fuel industry. High-level wastes are created in reprocessing spent fuel—the fuel that remains after the useful energy has been obtained from the nuclear chain reaction. Because nuclear wastes may be radioactive for hundreds or thousands of years, permanent disposal requires their isolation from the biosphere for at least that long.

Low-level nuclear wastes are generally buried in metal or concrete containers at designated commercial or Federal sites.

Roughly half of the commercial low-level wastes result from generation of nuclear power; the other half come from diagnosis and treatment of diseases and from other activities that use radioactive materials. As of 1979, 2.2 million cubic meters (77.7 million cubic feet) of low-level wastes had been buried in the United States, three-fourths at Federal sites. In addition, about 140 million tons of uranium mill tailings had been stored at the milling site.



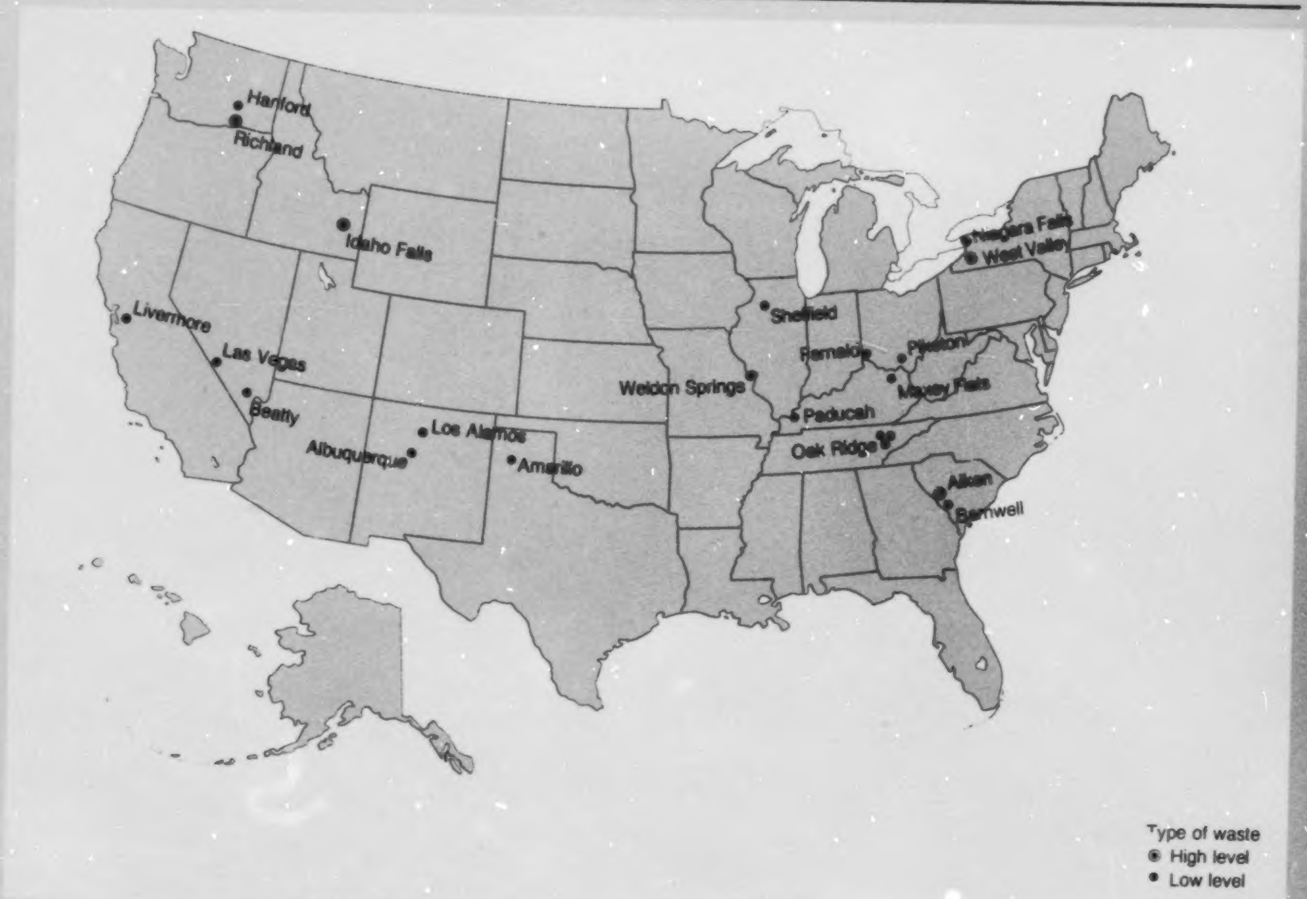
9-27

Radioactive waste disposal sites, 1979

A single 1,000-megawatt nuclear power plant generates about 25 tons of radioactive spent fuel per year, a high-level waste that must be disposed of permanently or stored for possible reprocessing later. No commercial reprocessing plants are now in operation, and spent fuel is stored at nuclear power plants.

To date, most high-level wastes have come from the production of nuclear weapons. These wastes and some from nuclear power reprocessing—a total of 269,000 cubic meters (9.5 million cubic feet)—are stored in steel tanks at four temporary locations. The most discussed method of permanent disposal is in deep geological formations such as rock salt deposits, in shale, in crystalline formations such as volcanic rock, and in metamorphic rock.

Low-level wastes are disposed of by shallow burial at 22 sites. As of December 1979, 5 were closed to new shipments.


Hanford
Richland
Idaho Falls
Livermore
Las Vegas
Beatty
Los Alamos
Albuquerque
Amarillo
Weldon Springs
Sheffield
Fernald
Piketon
Maxey Flats
Paducah
Oak Ridge
Aiken
Barnwell
Niagara Falls
West Valley
Type of waste
⦿ High level
● Low level

345

346

9-28

Production of hydropower, 1950–1978

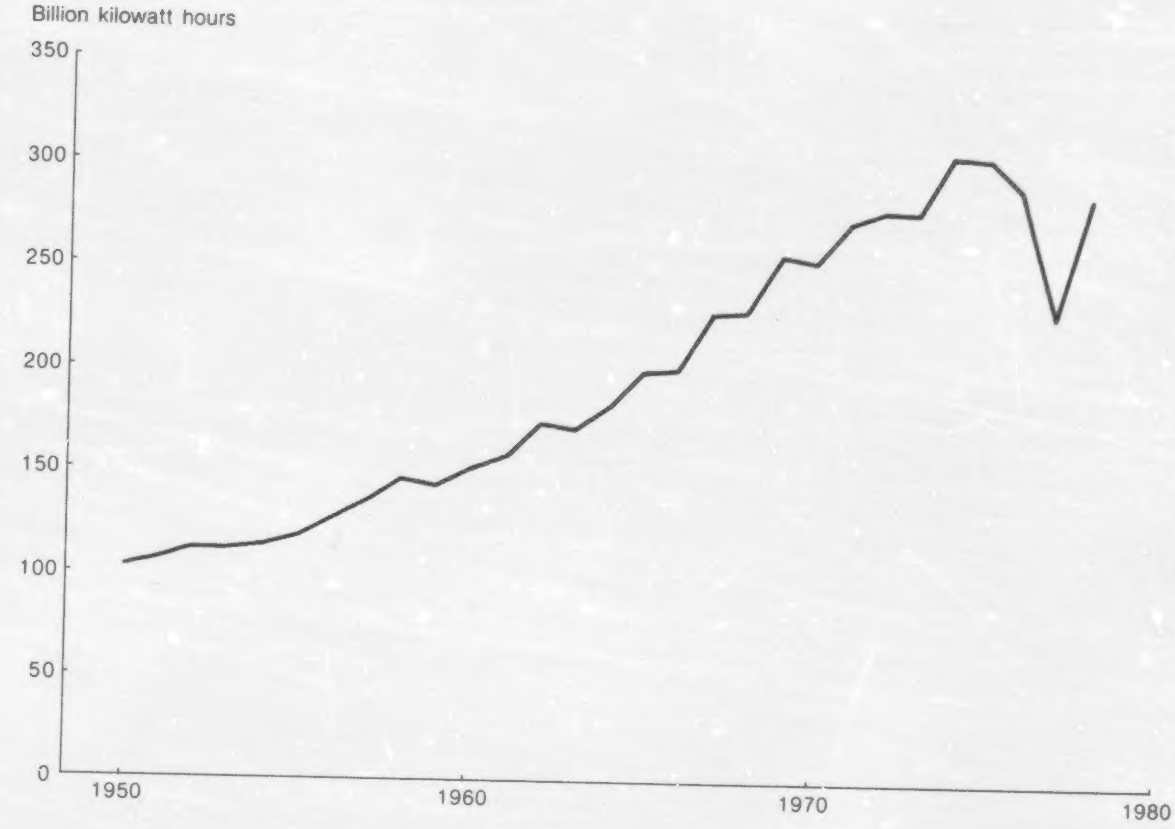
In addition to nuclear power and fossil fuels, there are many other sources of energy. They depend directly or indirectly on the sun. Solar sources include hydropower, geothermal, direct solar, biomass, wind, and photovoltaic cells.

Many of these new energy technologies are too new for trends to be clear, but interest is high and activity is accelerating.

The United States now produces 280 billion kilowatt hours of energy from hydropower annually. Almost all of it is transformed into electricity.

Although generation of hydropower has grown by about 4% each year for 28 years, it now supplies a decreasing percentage of total electricity. In 1950 it was 29.2%, and in 1978 it was 12.7%. The drop in 1977 resulted from a severe drought in the Pacific Northwest.

Hydropower is primarily a regional source of electricity. Most of the better sites have been developed, but growth is expected from operation of many small-scale sites, particularly in the Northeast. Additional large-scale facilities would conflict with other land and water uses.



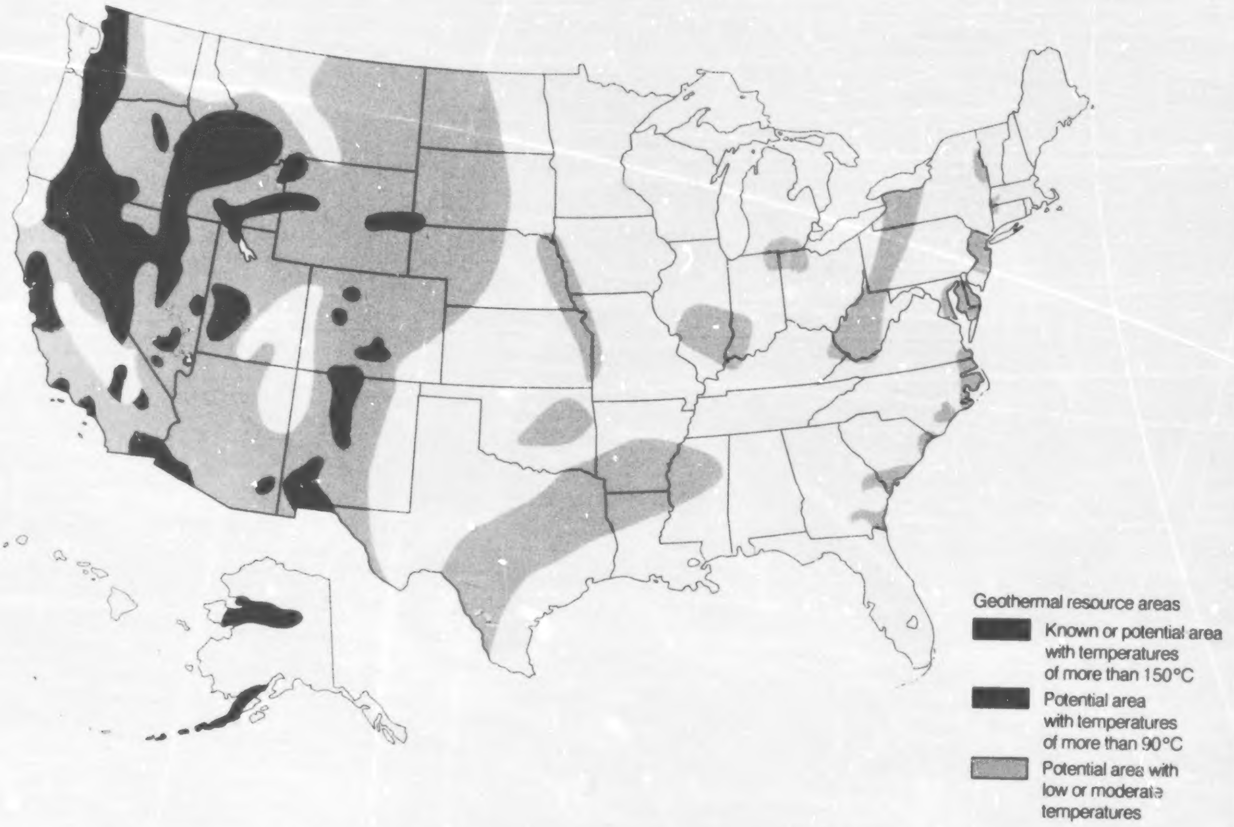
347 JEC

GPL

348

9-29

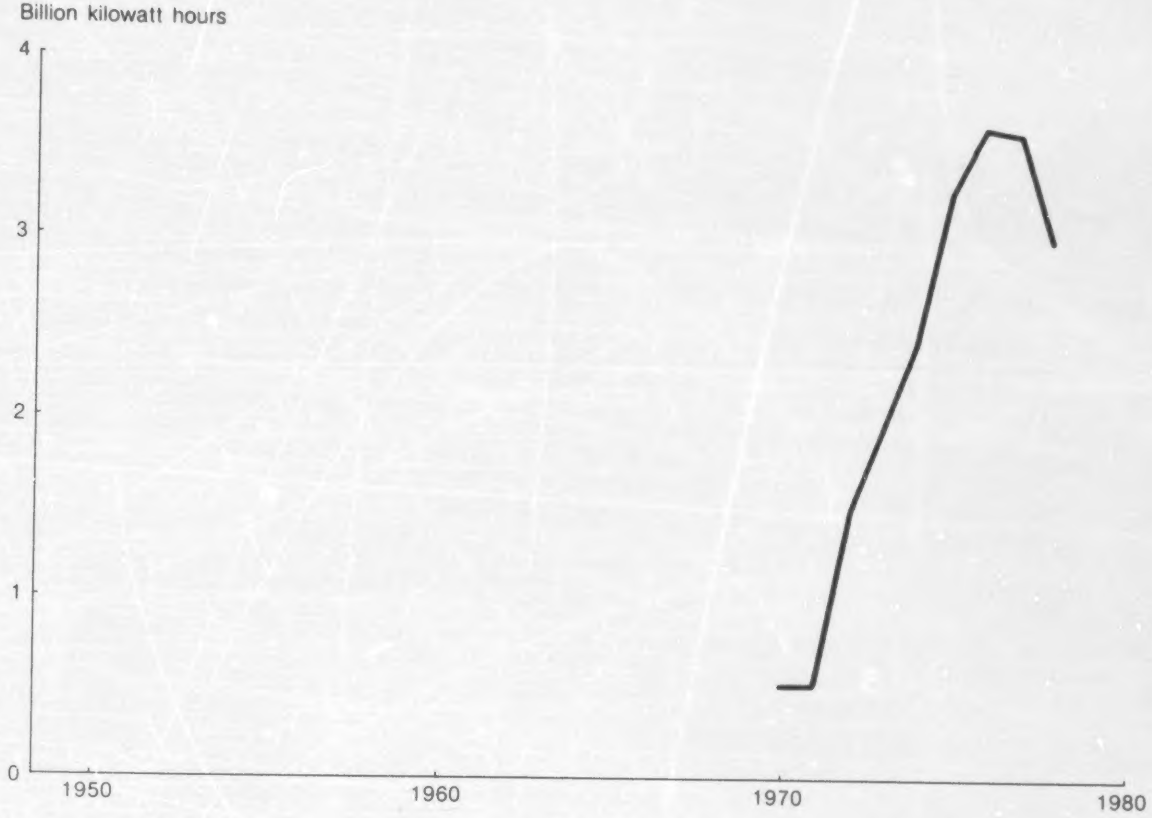
Geothermal resources, 1970s


Geothermal resource areas
Known or potential area with temperatures of more than 150°C
Potential area with temperatures of more than 90°C
Potential area with low or moderate temperatures

Geothermal resources consist of hot dry rock, steam, or hot water reservoirs trapped hundreds or thousands of feet beneath the surface of the earth. These resources are used primarily to generate electricity. Most areas of possible geothermal resource development are in the western and Rocky Mountain States.

9-30

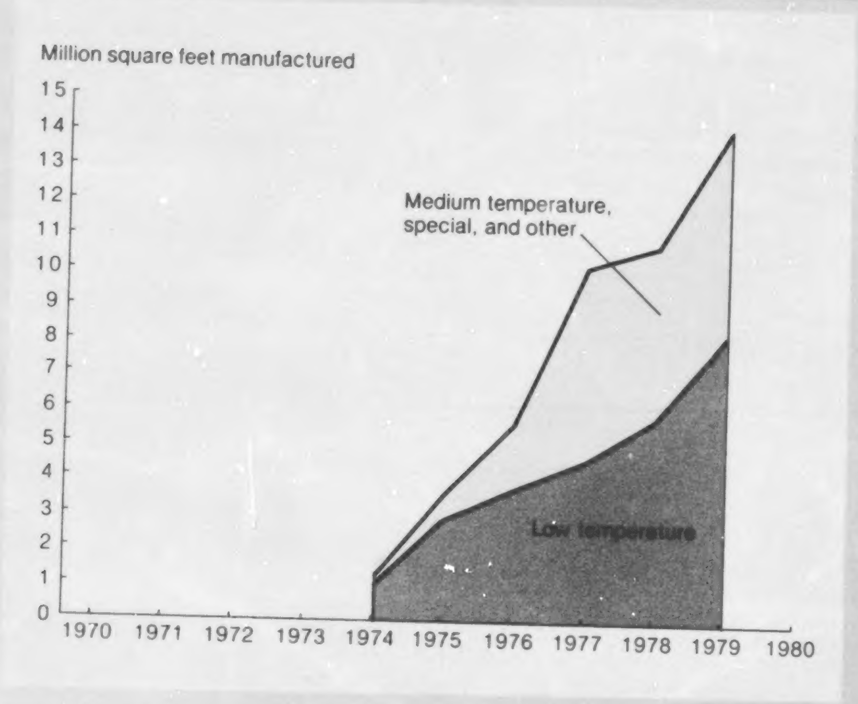
Production of electricity from geothermal resources, 1970–1978



The only producing geothermal facility is the Geysers in northern California. Output declined in 1977 and 1978 because of maintenance problems, but until then, the Geysers had provided as much as 0.18% of the domestic production of electricity.

350

9-31
Solar collectors manufactured, 1974–1979



The manufacture of low-temperature solar collectors, used primarily to heat swimming pools, has increased more than 7-fold in 5 years; the manufacture of medium-temperature collectors, used for space and domestic water heating, increased 40-fold at the same time.

Sources and technical notes

9-1
Energy consumption, by fuel type, 1850–1978

1850–1940, all fuel types, and 1950 fuelwood only: *Energy perspectives,* U.S. Department of the Interior (Washington: USGPO, 1975), p. 34.

1950–1978, except wood data: *Annual report to Congress,* 1978, U.S. Department of Energy, Energy Information Administration (Washington: USGPO, 1979), v. Two: Data, DOE/EIA-017312, p. 7.

These figures are estimates of the amount of energy used in homes, commercial establishments, transportation systems, and industry.

Forms of energy not marketed directly are not included (for example, energy derived from draft animals and water wheels in the 19th century).

The energy derived by the pulp and paper industry from its own waste products is not included.

Energy derived from all forms of biomass and not includes in the 1978 total ranges from 1.3 to 1.8 quads.

In addition, many other forms of energy make up a very small portion of the total: Direct solar, currently estimated at 1/200 of 1% of all energy consumed, windmills, and photovoltaic cells.

For 1950–1978, coal includes bituminous, lignite, and anthracite. Natural gas excludes natural gas plant liquids. Oil includes natural gas liquids and crude oil burned as fuel. Hydropower includes electric utility and industrial generation of hydropower and net electricity imports. Geothermal and other include wood, refuse, and other biomass fuels used to generate electricity.

Data for 1978 are preliminary.

9-2
Energy consumption, by fuel type, 1950–1978

Annual report to Congress, 1978, U.S. Department of Energy, Energy Information Administration (Washington: USGPO, 1979), v. Two: Data, DOE/EIA-017312, p. 7.

Data for 1978 are preliminary.

9-3
Net trade in energy resources, 1950–1978

See 9-2, p. 11.

Total includes coke and electricity generated from coal, for which net trade was – 0.31 quads in 1978.

Oil includes crude oil and refined petroleum products including unfinished oils and natural gas plant liquids.

Data for 1978 are preliminary.

9-4
Energy production, by fuel type, 1850–1978

1850–1940: *Historical statistics of the United States, colonial times to 1970,* U.S. Bureau of the Census (Washington: USGPO, 1975), pp. 587–588.

1950–1978: See 9-2, p. 5.

Coal, 1850–1940, includes bituminous and Pennsylvania anthracite; 1950–1978, include bituminous, lignite, and anthracite.

Wood data are for consumption, not production.

Natural gas, 1950–1978, excludes natural gas plant liquids.

Oil, 1950–1978, includes crude oil, lease condensate, and natural gas liquids.

Geothermal includes wood, refuse, and other biomass fuels used to generate electricity.

Data for 1978 are preliminary.

9-5
Energy production, by fuel type, 1950–1978

See 9-2, p. 5.

Other includes wood, refuse, and other biomass fuels used to generate electricity.

9-6
Energy flow in the U.S. economy, 1975

"Annual U.S. energy use drops again," U.S. Bureau of Mines, news release, April 5, 1976, adapted from *Man, energy, society,* Earl Cook (San Francisco: W. H. Freeman & Company, 1976), p. 313.

Food energy is excluded.

Hydropower is computed as 100% efficient.

Changes in inventories, invariably relatively small, are included in net imports or exports.

Industrial consumption includes nonfuel uses of energy resources (asphalt, petrochemicals).

Efficiency figures used to disaggregate useful heat and work from waste are very rough estimates of first-law efficiency: Household/commercial, 72%; transportation, 15%; industrial, 40%. Electric generation efficiency averages about 38% when hydropower is included.

9-7
Energy consumption, by sector, 1950–1978

See 9-2, p. 9.

Data for 1978 are preliminary.

9-8
Energy consumption, by end use, 1950–1978

See 9-2, p. 9.

Energy consumption is allocated in proportion to sales by privately owned Class A and B electric utilities, which accounted for 78% of the market in 1977.

Miscellaneous includes coal used to run mine machinery, coal sales to mine employees, and changes in mine inventories of coal.

Data for 1978 are preliminary.

9-9
Residential heating, by fuel type, 1940–1975

Residential energy uses, U.S. Bureau of the Census (Washington: USGPO, 1978), current housing reports, series H-123-77.

9-10
Residential heating, by fuel type and county, 1970

See 9-9.

9-11
Per capita energy consumption and gross domestic product for four nations, 1961–1977

Energy consumption, 1961: *Energy balances of OECD countries, 1974/1976,* Organization for Economic Cooperation and Development, International Energy Agency (Paris, 1978), p. 26.

1962–1977: *Energy balances of OECD countries, 1975/77* (Paris, 1979), p. 88.

Gross domestic product and population, 1961: *National accounts of OECD countries, 1976* (Paris, 1978), v. 1. 1962–1977: *National accounts of OECD countries, 1952–1977* (Paris, 1979), v. 1, pp. 133, 146.

One metric ton of crude oil equals 43 million Btu.

Gross domestic product excludes income originating overseas.

GDP is computed here using market exchange rates.

9-12
Energy consumed by sector for nine nations, 1972

How industrial societies use energy—a comparative analysis, Joel Darmstadter, Joy Dunkerley and Jack Alterman (Baltimore: The Johns Hopkins University Press, 1977), p.187. Published for Resources for the Future.

9-13
Energy supply systems for fossil fuels

MERES and the evaluation of energy alternatives, Council on Environmental Quality (Washington: USGPO, 1975), p. 6, adapted from *The reference energy system and associated data base,* Murray D. Goldberg (Upton, N.Y.: Brookhaven National Laboratory, 1974), BNL 19263.

9-14
Coal fields, 1970s

Coal resources of the United States, January 1, 1974, Paul Averitt, U.S. Geological Survey (Washington: USGPO, 1975), bulletin 1412, p. 5.

9-15
Coal production, 1900–1978

1900–1913: *Coal mining fatalities in the United States, 1870–1914, with statistics of coal production, labor and mining methods by States and calendar years,* U.S. Bureau of Mines (Washington, D.C., 1916), p. 10.

1914–1966: Bituminous Coal Operators, unpublished data. Pennsylvania Department of the Environment, unpublished data.

1967–1978: *Injury experience in coal mining, 1978,* U.S. Department of Labor, Mine Safety and Health Administration (Washington: USGPO, 1980), informational rep. 1112, table 2, p. 13, and previous annual issues.

Surface, 1967–1978, includes strip mining, augering, culm banks, and dredging.

9-16
Land disturbed and reclaimed by the coal mining industry, 1930–1978

1930–1978: U.S. Bureau of Mines, unpublished data.

Data are for bituminous, subbituminous, and lignite coal only.

Land disturbed includes that used in surface and underground mining and for coal-cleaning plant wastes.

Reclamation data include land reclaimed by the industry, not through State and private efforts.

Although State requirements differ, mine operators are generally required to revegetate disturbed land.

Acreage includes only initial reclamation.

Data for 1978 are preliminary.

9-17
Streams affected by acid mine drainage, 1970s

Water atlas of the United States, Water Information Center, Inc. (Port Washington, N.Y., 1973), plate 57.

9-18
Coal mine deaths from accidents, 1906–1978

Injury experience in coal mining, 1978, U.S. Department of Labor, Mine Safety and Health Administration (Washington: USGPO, 1980), informational rep. 1112, table 2, p. 13, and previous annual issues.

From 1901 to 1978, 110,939 deaths resulted from mining accidents.

Data for 1906–1909 include only States with complete records of fatal injuries. They represent 98%-99% of the total coal production; 1910–1978 data include the entire coal industry.

Underground includes fatalities from roof and face falls, haulage equipment, gas and dust explosions, explosives, electricity, machinery, pressure bumps and bursts, and inrushes of water or material.

Surface includes fatalities at all other work locations, including underground mines' surface works, strip mines, culm banks, dredges, and mechanical-cleaning plants. Beginning in 1955, includes fatalities in auger mines.

9-19
Natural gas and oil fields, 1970s

Energy perspectives 2, U.S. Department of the Interior (Washington: USGPO, 1976), p. 91.

Final environmental statement, proposed five-year OCS oil and gas lease sale schedule March 1980–February 1985, U.S. Department of the Interior, Bureau of Land Management (Washington: USGPO, 1980), pp. 40–41.

9-20
Natural gas and oil production, 1950–1978

See 9-2, p. 5.

Data exclude natural gas liquids.

Crude oil data include lease condensate.

9-21
Liquified natural gas facilities, 1980

"LNG facilities located in the United States," U.S. Department of Transportation, Office of Operations and Enforcement (February 1980).

9-22
The nuclear fuel cycle

Based on *Annual report to Congress, 1977*, U.S. Department of Energy, Energy Information Administration (Washington: USGPO, 1978), v. Two, Executive summary, projections of energy supply and demand and their impacts, DOE/EIA-0036/2, p. 192.

9-23
Nuclear reactors built, being built, or planned, September 1973–December 1979

Program summary report, U.S. Nuclear Regulatory Commission (Springfield, Va.: National Technical Information Service, 1980), v. 4, n. 1, p. 1–4, and previous monthly issues.

9-24
Nuclear reactors, December 1979

Program summary report, U.S. Nuclear Regulatory Commission (Springfield, Va.: National Technical Information Service, 1980), v. 4, n. 1, p. 1–4.

9-25
Nuclear power generation, 1957–1979

1957–1978: See 9-2, p. 135.

1979: *Monthly Energy Review*, February 1980, p. 72.

Data include electric utility plants only. They cover all plants, including those in operation and those that have been shut down. Most of the latter were test or prototype units.

9-26
Low-level radioactive wastes disposed of, 1962–1979

Commercial, 1962–1978: "Inventory (1962–1978) and projections (to 2000) of shallow land burial of radioactive wastes at commercial sites: An update," W. F. Holcomb, *Nuclear Safety* 21:380 (May–June 1980). 1979: "Inventory of shallow land disposal of radioactive wastes at commercial sites (1962–1979): An update," W. F. Holcomb, U.S. Environmental Protection Agency (Draft, 1980), technical note EPA-ORP/TAD-80-6, table 2, p. 5.

Federal, 1976–1979: U.S. Department of Energy, unpublished data.

It is estimated that by 1985 there will have been 1.5–2.7 million cubic meters of low-level wastes generated in the United States.

9-27
Radioactive waste disposal sites, 1979

Report to the President by the Interagency Review Group on Nuclear Waste Management, U.S. Department of Energy (Springfield, Va.: National Technical Information Service, 1979), tables 9, 10, 15, pp. D-12, D-14, D-19.

High-level wastes include spent fuel (an estimated 2,300 metric tons of heavy metal) stored temporarily at nuclear power plants.

It is estimated that by 1985 there will be 258,000 cubic meters of high-level wastes in the United States, a decrease of 11,000 cubic meters since 1977 as a result of the processing of the wastes to reduce their liquid content.

As of December 31, 1979, closed sites included: National Lead Co. of Ohio, Niagara Falls, N.Y.; Nuclear Engineering Co., Maxey Flats, Ky. and Sheffield, Ill.; Nuclear Fuel Services, Inc., West Valley, N.Y.; and Weldon Springs, St. Charles County, Mo.

There are two disposal sites in Hanford, Wash., one for Department of Energy high-level and low-level wastes, the other for commercial low-level wastes.

9-28
Production of hydropower, 1950–1978

See 9-2, p. 5.

9-29
Geothermal resources, 1970s

"Geothermal energy and our environment," U.S. Department of Energy (Washington, D.C., 1980), DOE/EV-0088.

9-30
Production of electricity from geothermal resources, 1970–1978

See 9-2, p. 149.

9-31
Solar collectors manufactured, 1974–1979

Solar collector manufacturing activity, July 1978 through December 1979, U.S. Department of Energy (Washington: USGPO, 1980), table 1, p. 2.

Chapter 10

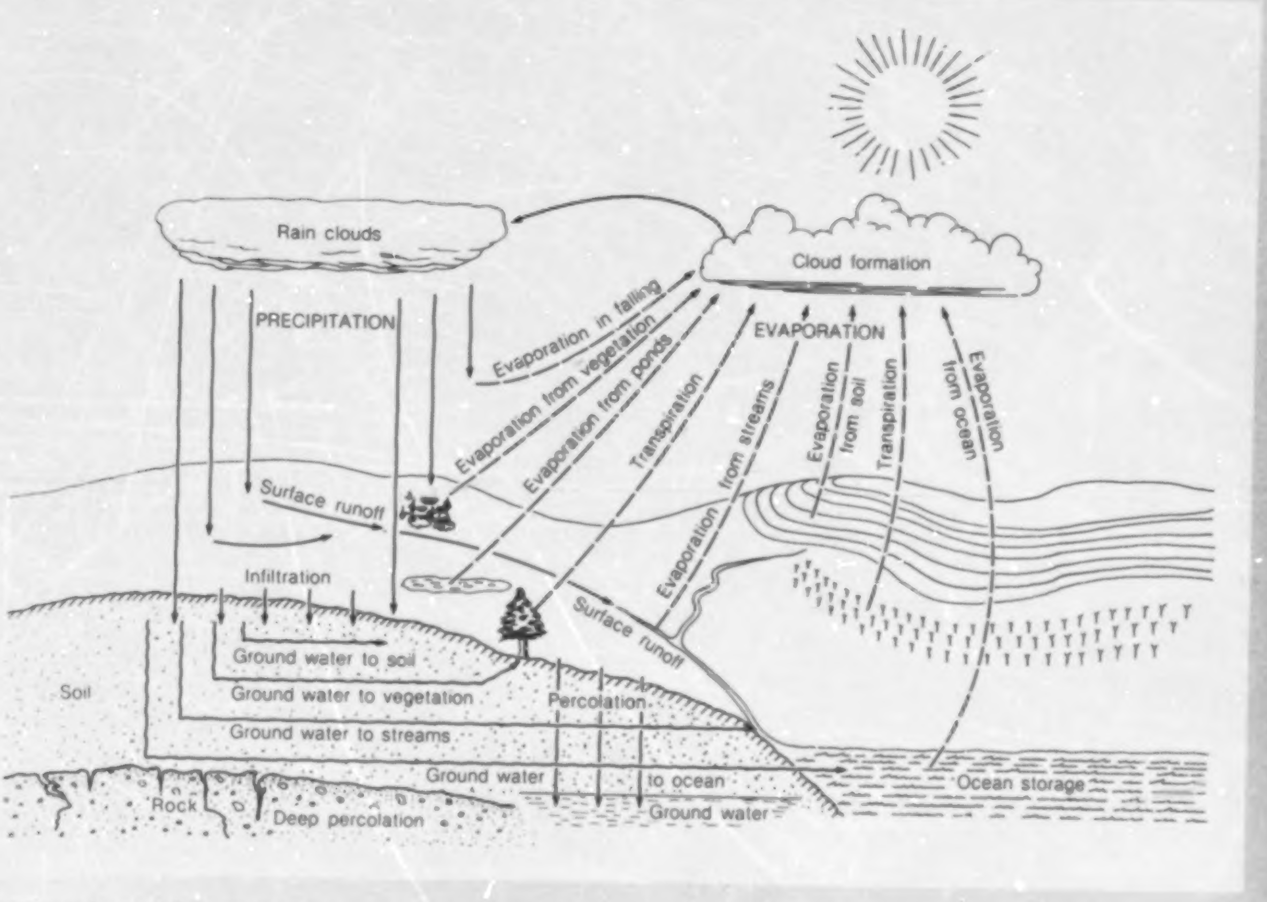
Water Resources

Social and industrial development has generally followed water sources, particularly rivers, natural harbors, and large lakes. Often the flow of water was altered in some way to meet a need, but technology was limited and so was success. With advanced technology, it is possible to irrigate millions of acres of northern plains and western lands with water diverted from the rivers of one region to the dry areas of another. Extensive water supplies are drawn from ground water storage, river flow is controlled by dams and locks, weather is modified to create local precipitation, and water is desalinated.

A problem with water is that there is often too much or too little of it. During extended droughts, there is usually no alternative to reducing use until the supply is recharged. But in the long run, the emphasis has been on securing more water.

As water demands for irrigation, industry, energy, and public supplies increase, competition develops among the users. One of the most intense conflicts is between offstream uses for economic and social growth and instream uses for fish, wildlife, and recreation. The growth of these conflicts is not surprising, for water is the most important of all renewable resources. All life depends on it.

10-1
The hydrologic cycle

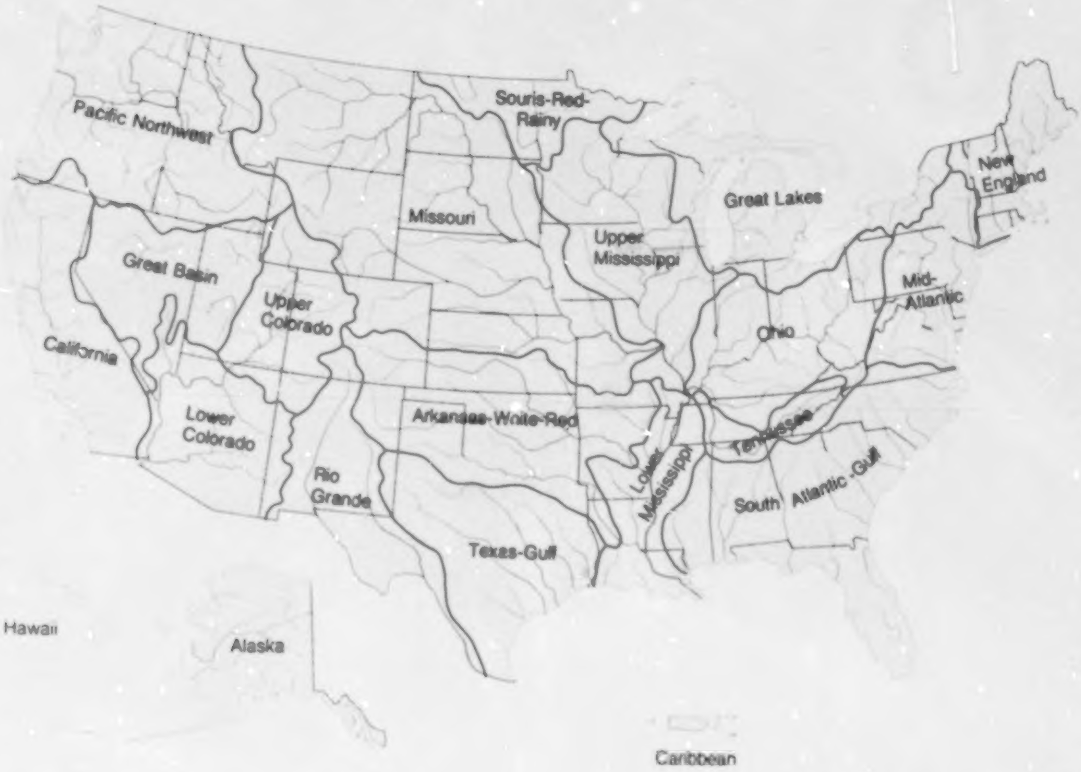

Rain clouds
Cloud formation
PRECIPITATION
EVAPORATION
Evaporation in falling
Evaporation from vegetation
Evaporation from ponds
Transpiration
Evaporation from streams
Evaporation from soil
Transpiration
Evaporation from ocean
Surface runoff
Infiltration
Surface runoff
Ground water to soil
Soil
Ground water to vegetation
Percolation
Ground water to streams
Ground water
to ocean
Ocean storage
Rock
Deep percolation
Ground water

Water moves in an endless cycle of precipitation and evaporation. Precipitation takes the form of rain, snow, sleet, and hail. It evaporates, is transpired through plants, seeps into the ground, runs into lakes or impoundments, or flows into rivers and streams and then to the sea. About 30% runs into surface waters, waters that largely supply human needs. These waters are then fed back into streams and lakes, or are returned to the atmosphere by evaporation.

In the end, nothing is lost, although it may take a single molecule of water days, weeks, years, or millenia to complete the cycle.

10-2

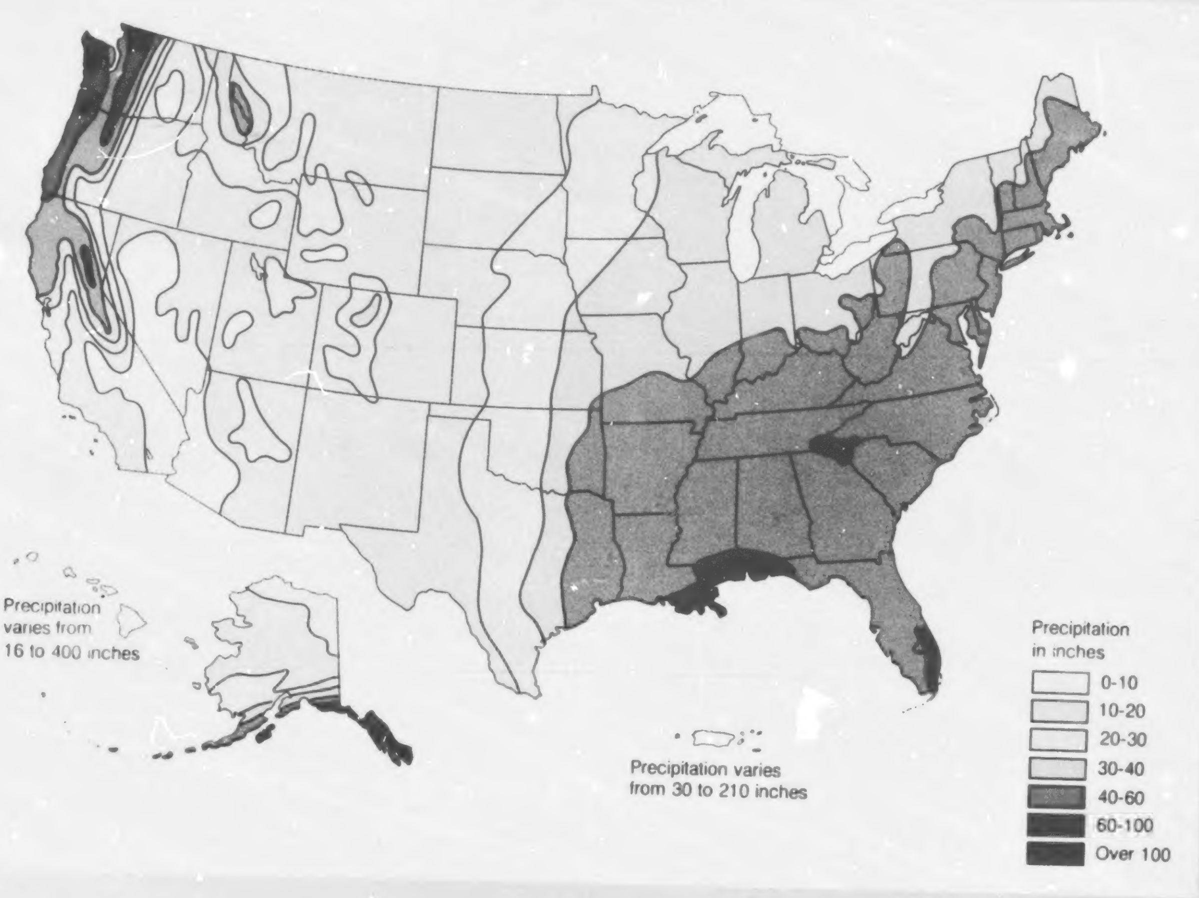
Water resource regions, 1975


Pacific Northwest
Souris-Red-Rainy
Missouri
Great Lakes
New England
Upper Mississippi
Great Basin
Upper Colorado
Mid-Atlantic
Ohio
California
Lower Colorado
Arkansas-White-Red
Tennessee
Lower Mississippi
Rio Grande
South Atlantic-Gulf
Texas-Gulf
Hawaii
Alaska
Caribbean

The 3 million miles of rivers and streams, 78,267 square miles of inland water (small lakes, reservoirs, and ponds of 40 or more acres), and 60,878 square miles of the Great Lakes are grouped into 21 regions by the Water Resources Council. Each contains a major river basin or a series of small rivers and basins.

2

10-3
Average annual precipitation, 1931-1960


Precipitation varies from 16 to 400 inches
Precipitation varies from 30 to 210 inches
Precipitation in inches
0-10
10-20
20-30
30-40
40-60
60-100
Over 100

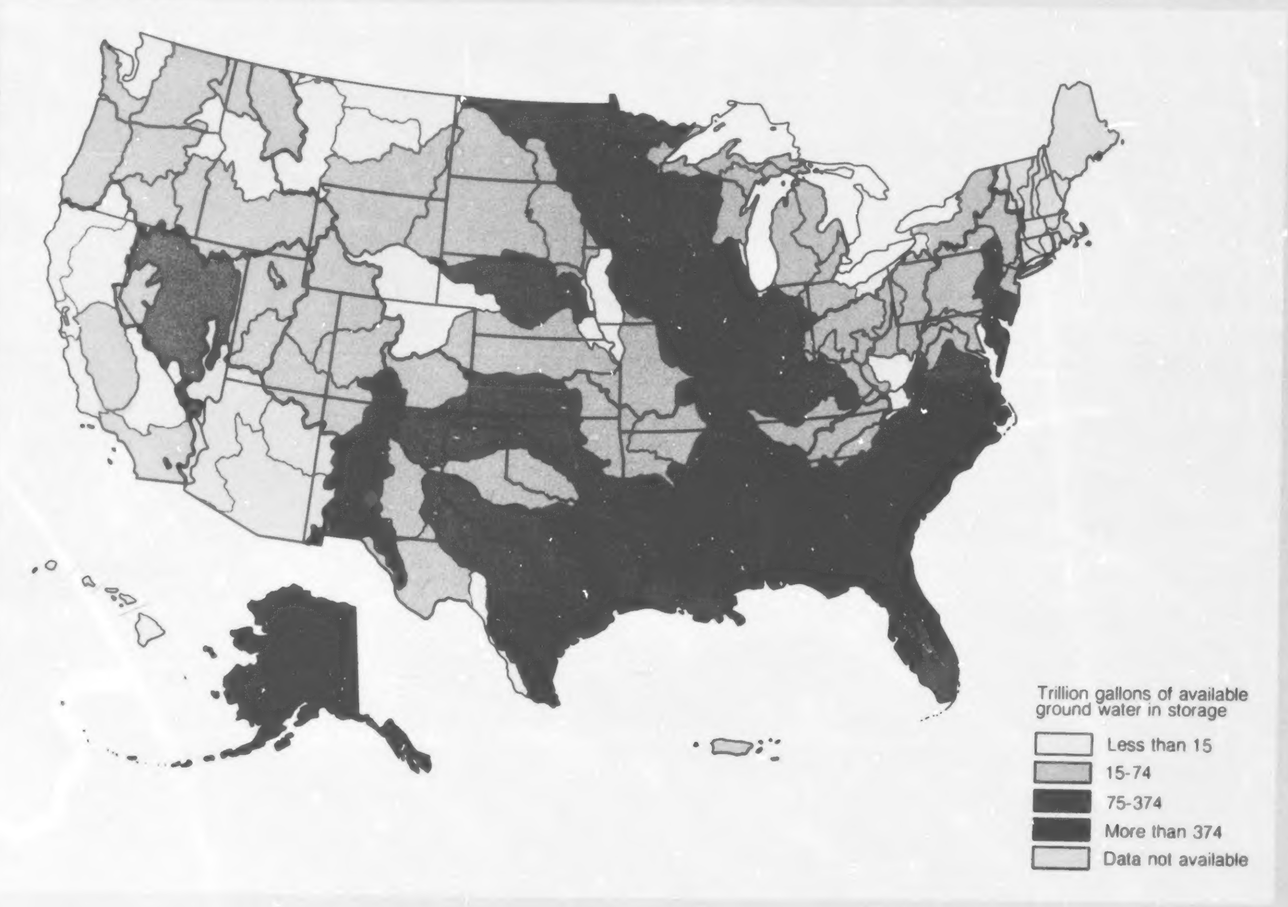
Although precipitation averages 30 inches per year, it is very unevenly distributed. The area east of the Mississippi River receives the most. It averages 44 inches per year, the Great Plains averages 28 inches, and the area west of the Rockies averages only 18 inches per year.

These figures obscure the wide range that exists. There are areas in the Great Basin and the Lower Colorado regions that receive less than 4 inches per year, and some of the Pacific Northwest receives 200 inches per year. Mt. Waialeale, Hawaii, has the world record of 460 inches per year. Just 15 miles to the southwest, annual rainfall is less than 30 inches. The world average is 35 inches.

360

361

10-4
Available ground water, 1975


Trillion gallons of available ground water in storage
Less than 15
15-74
75-374
More than 374
Data not available

The volumes of water in the porous layers of underground rock are known as aquifers. Much of this ground water is potable. Most of it accumulated over geologic time, and because of its location, it cannot be recharged once it is depleted. Some is renewed by percolation of rain or snowmelt.

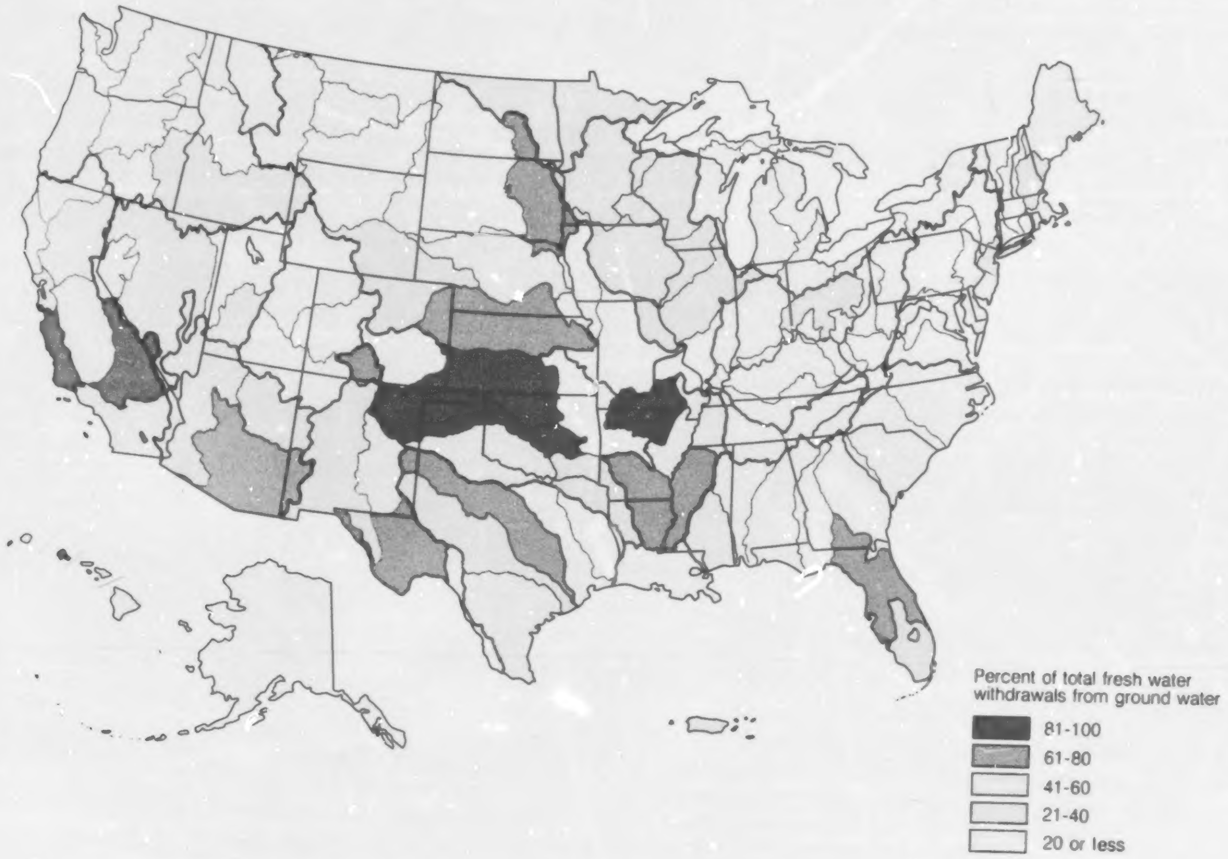
In the aggregate, there are between 33,000 trillion and 59,000 trillion gallons of ground water within a half mile of land surface. Some 16,000 trillion gallons are available for extraction, but only about 400 trillion gallons are available on a renewable basis.

The largest volumes of ground water are in the Southeast and Midwest, areas with extensive surface waters.

☐ Available ground water can be extracted. Total ground water refers to a larger volume, that which theoretically exists but cannot be extracted because of extraction costs, environmental considerations, current technology, or geologic formations.

10-5

Ground water withdrawal, 1975


Percent of total fresh water withdrawals from ground water
81-100
61-80
41-60
21-40
20 or less

Ground water is a major source of fresh water for much of the country. Roughly half the population now depends on ground water for domestic use, which includes drinking water.

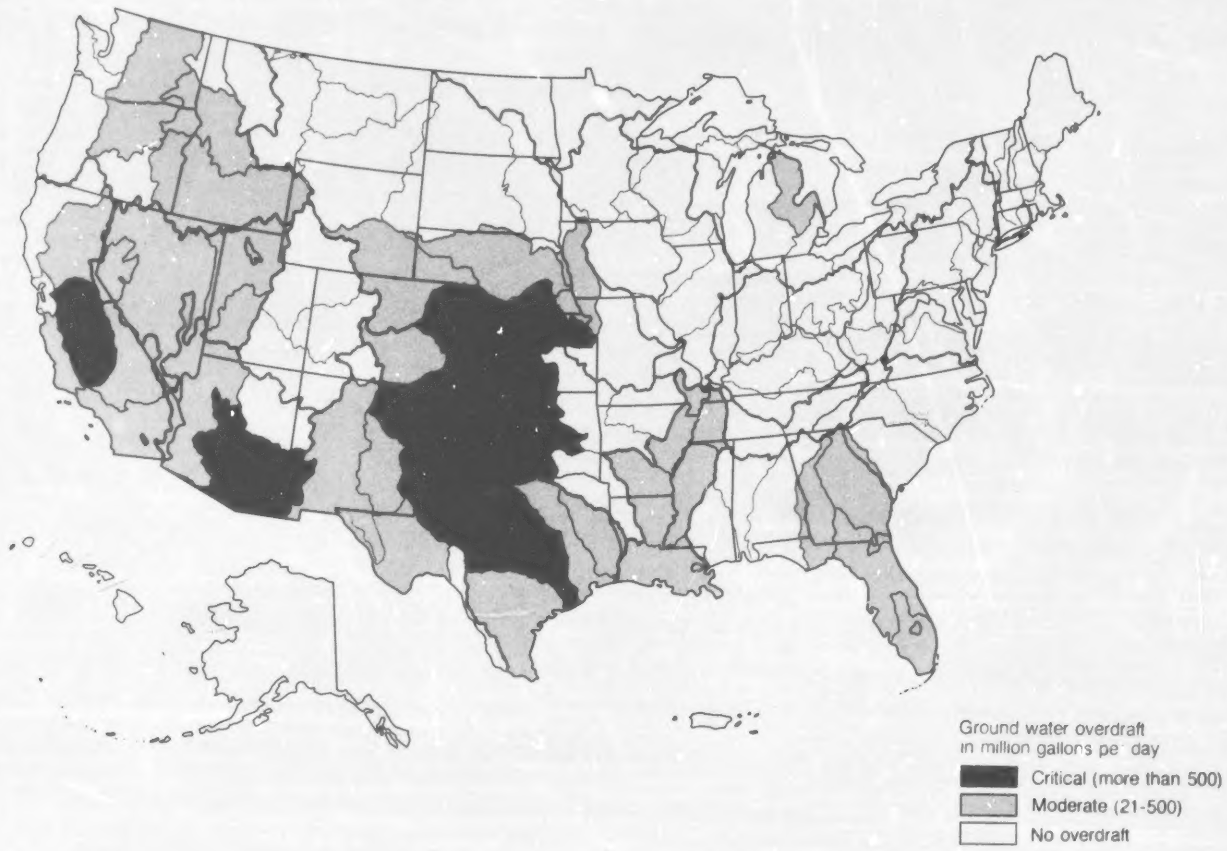
Some areas of the West and the High Plains rely on ground water for 80% or more of their fresh water.

364

365

10-6

Ground water overdraft, 1975


Ground water overdraft
in million gallons per day
■ Critical (more than 500)
▨ Moderate (21-500)
□ No overdraft

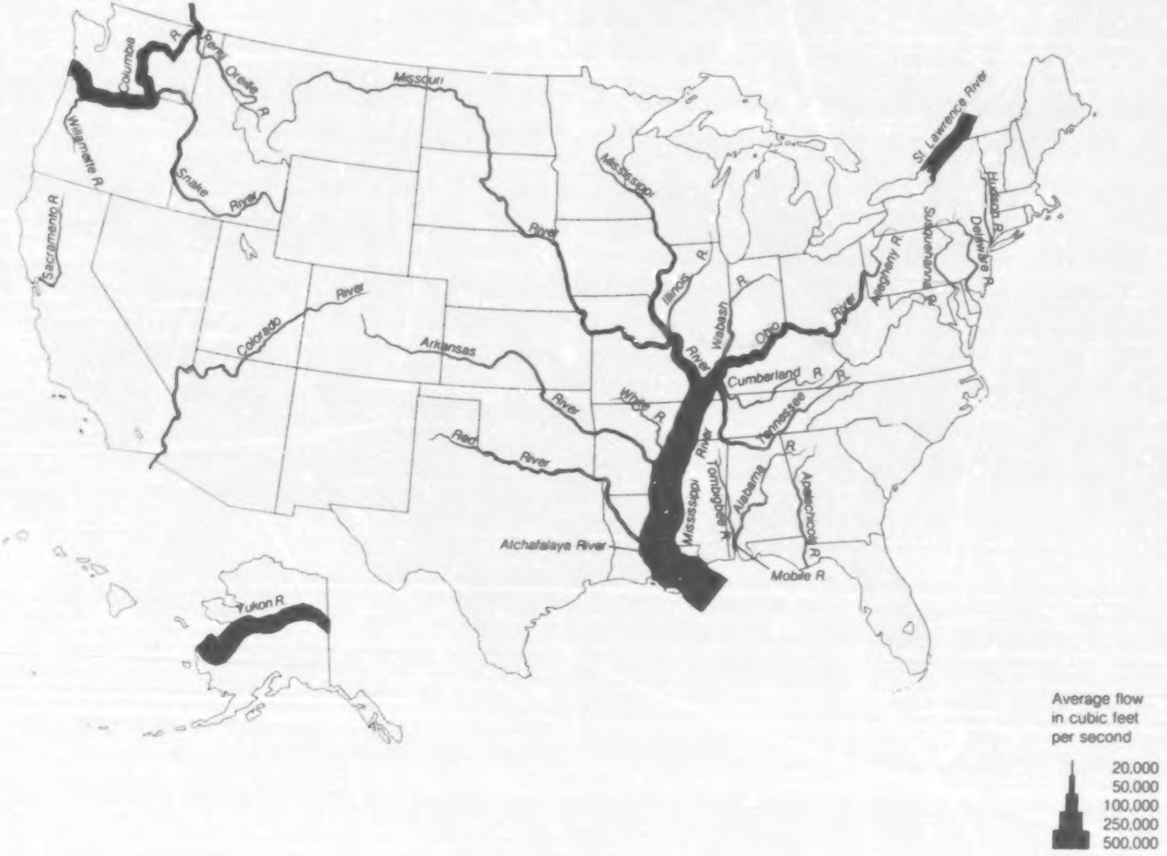
Overdraft of ground water occurs when water is withdrawn from sources that cannot be renewed or is withdrawn more quickly than they can be recharged.

Of the 106 Water Resources Council subregions, the overdraft in 8 is considered critical—that is, more than 500 million gallons of water are withdrawn per day; and in 30, ground water overdraft is moderate—21 to 500 million gallons per day. Ground water overdraft is a serious problem in the High Plains from Nebraska to Texas and in parts of Arizona and California.

366,3E

367

10-7
Average streamflow of large rivers, 1941–1970

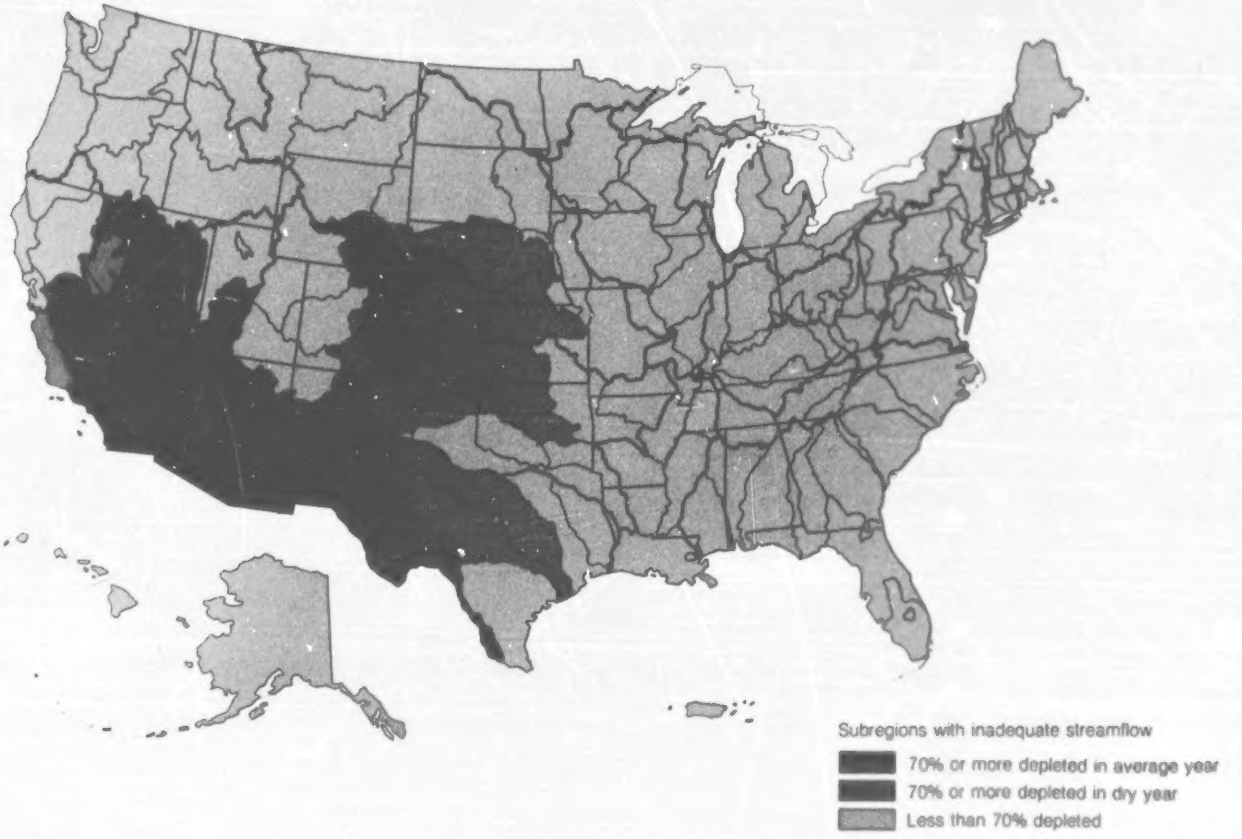

Columbia
R.
Pend Oreille R.
Missouri
Willamette R.
Snake River
Sacramento R.
Colorado River
Arkansas River
Mississippi River
Illinois R.
Wabash R.
Ohio River
Allegheny R.
Susquehanna R.
Hudson R.
Delaware R.
St. Lawrence River
Cumberland R.
Tennessee R.
White R.
Red River
Mississippi River
Tombigbee R.
Alabama R.
Apalachicola R.
Mobile R.
Atchafalaya River
Yukon R.
Average flow in cubic feet per second
20,000
50,000
100,000
250,000
500,000

Water that does not infiltrate soil and rock and is not retained in surface reservoirs, lakes, or underground reservoirs becomes streamflow. Seventy-five percent of the flow that reaches an ocean or crosses U.S. boundaries is delivered by 11 rivers or river systems.

The Mississippi is by far the largest. Almost 650,000 cubic feet of water pass out of the Mississippi River into the Gulf of Mexico each second, an amount that is equal to 419 billion gallons per day. The Mississippi receives the flow of seven other large rivers: the Illinois, Missouri, Ohio, Tennessee, White, Arkansas, and Red, and in the process drains 40% of the land area of the conterminous States.

Total streamflow in the lower 48 States is 1.86 million cubic feet per second. Alaska, Hawaii, and Puerto Rico raise the total to 2.78 million cubic feet per second.

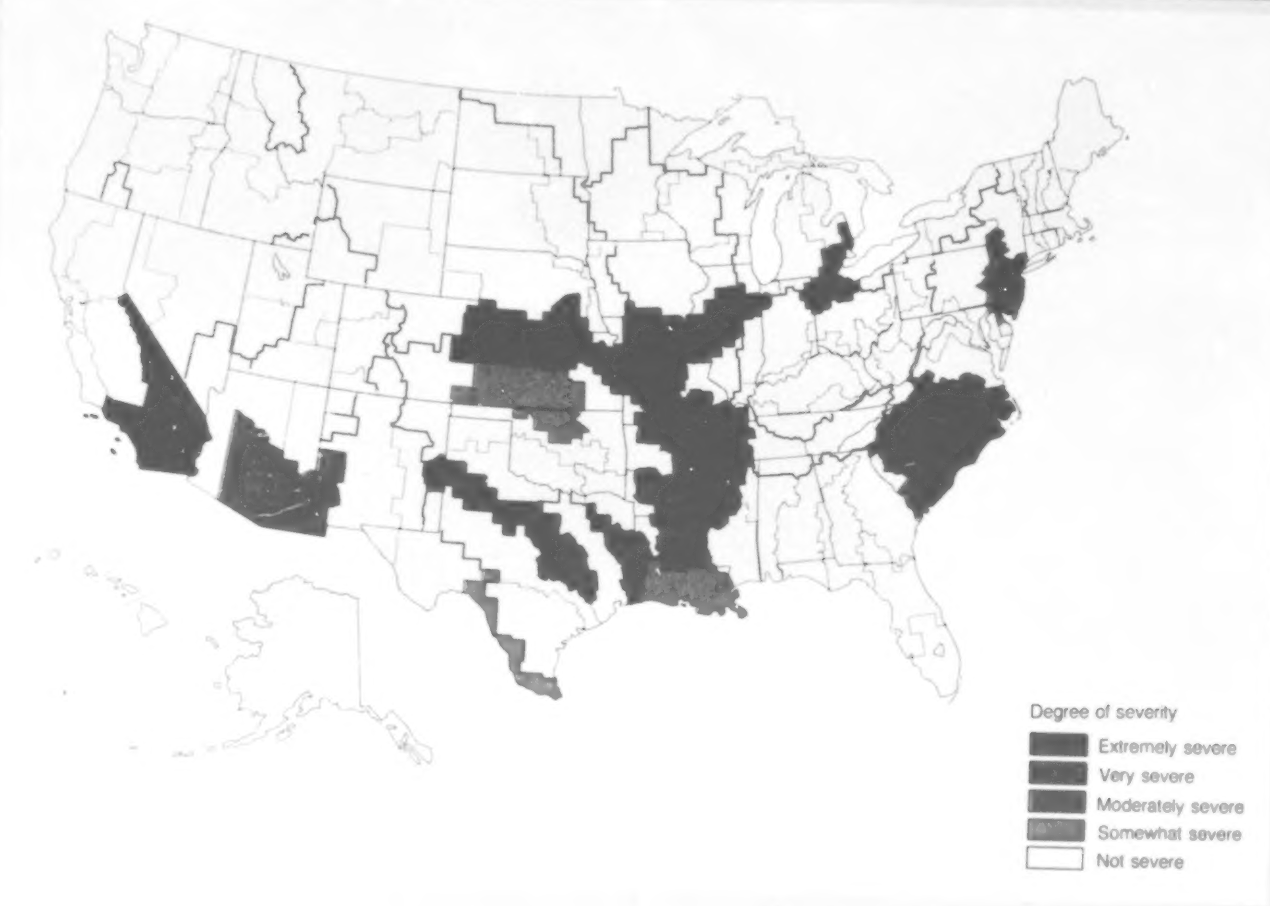
10-8
Inadequate surface water supply for instream use, 1975


Subregions with inadequate streamflow
▆ 70% or more depleted in average year
▆ 70% or more depleted in dry year
▒ Less than 70% depleted

Increased demand is causing significant competition among major users of water. Streamflow in 14 of the 106 subregions is inadequate to support navigation, hydropower, recreation, fish, wildlife, and other instream uses in an average year. Inadequate means that 70% or more of the water is consumed offstream during a given year. In a dry year, nine more subregions are in the 70% or more depletion category.

There are frequent conflicts between water stored for hydropower operations and the minimum flow needed below the impoundments for fish and wildlife habitat and recreation. A potential conflict in some western States is the use of water for irrigation and for the extraction and transport of coal and oil shale.

10-9
Flooding problems, 1975

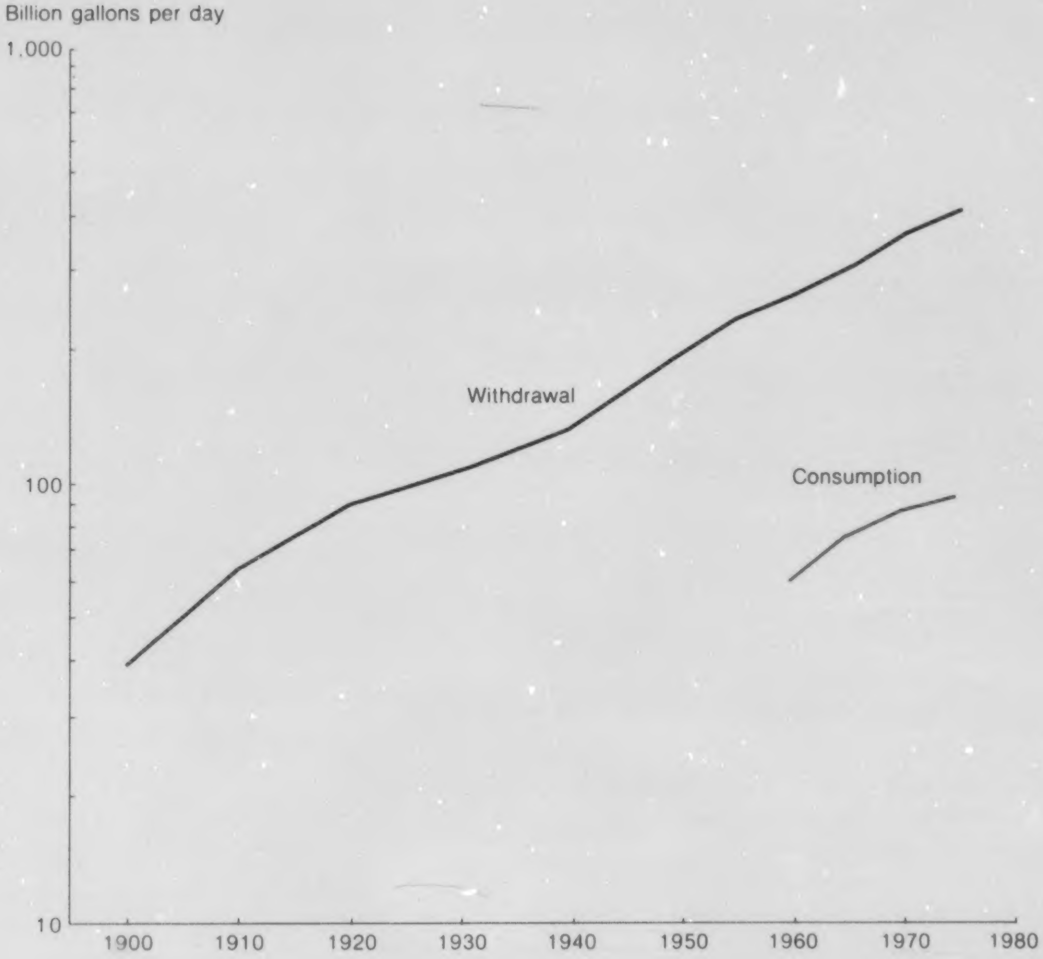

Degree of severity
Extremely severe
Very severe
Moderately severe
Somewhat severe
Not severe

Floods occur when a stream, lake, or bay can no longer contain the water within its natural or artificial banks.

Excessive runoff from snowmelt, rain, or a combination of the two causes most of the spring floods in the northern States. Thunderstorms, usually in summer, pose a threat to small watersheds throughout the country. Hurricanes and accompanying tidal flooding endanger Gulf and Atlantic coastal areas.

Periodic flooding affects many areas. Extreme problems are found along the North Carolina coast, in the greater New York metropolitan area, and in parts of the Ozarks and the Lower Mississippi basin.

10-10
Water use, 1900–1975

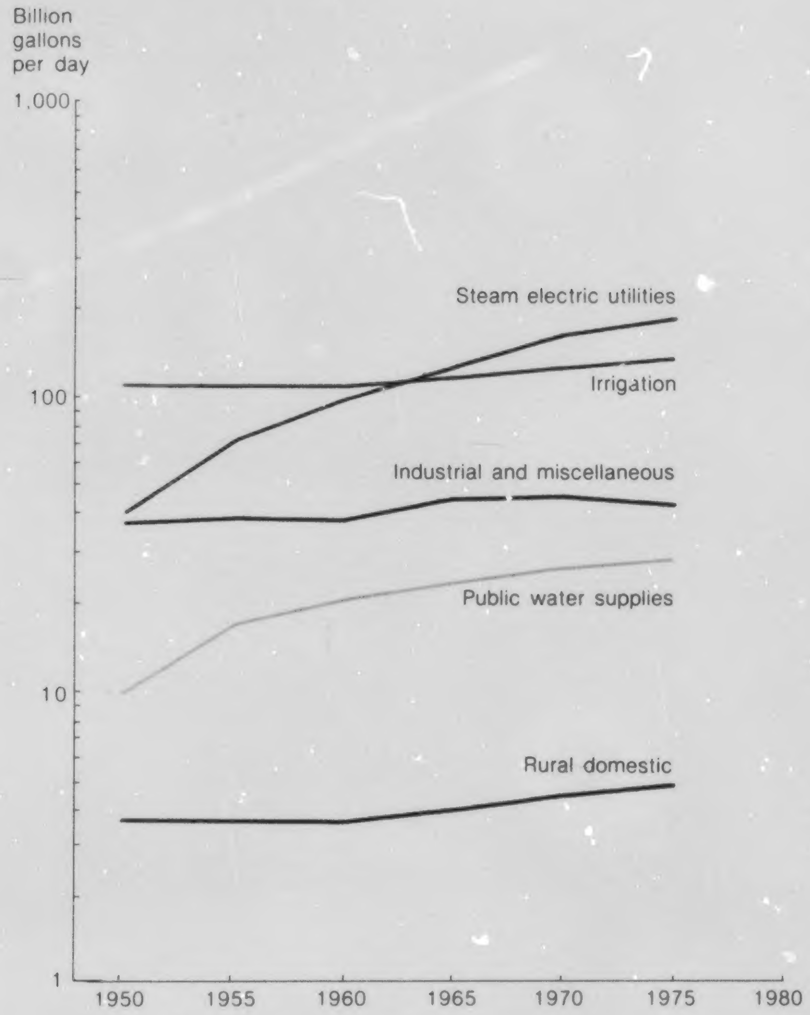


Two measures of water use are withdrawal and consumption. Water is withdrawn when it is taken from a ground or surface source and is conveyed to the place of use. Water is consumed when it is no longer available for use because it has been removed from available supplies by evaporation, by transpiration, or by use in agriculture, manufacturing, or as food.

Water withdrawals for all purposes in 1975 averaged about 420 billion gallons per day—roughly 1,900 gallons of water per person per day. Less than a fourth of it was consumed. The remainder was returned to surface waters.

Withdrawals have increased 10-fold since 1900. The increase is a result partly of a growing population but, more important, of irrigation, industrial production, energy development, and water-intensive home appliances.

10-11
Water withdrawal, by use, 1950–1975



The largest increase in water withdrawls between 1965 and 1975 was for thermoelectric power. This industry uses fresh water and, increasingly often, salt water for condenser and reactor cooling. A large part of the increase, particularly in California and Nebraska, is from ground water.

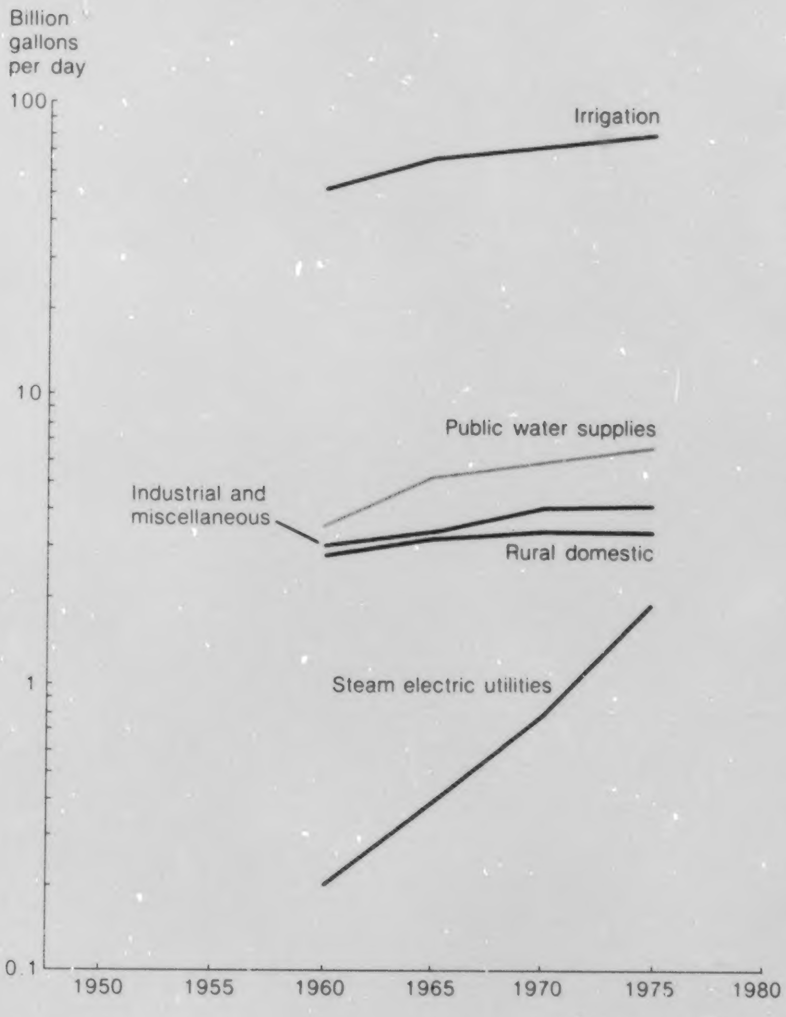
Withdrawals for irrigation, rural domestic uses, and public supplies increased about 8% during the decade; industrial use decreased about 4%.

The rate of water withdrawal is higher in the West than in the East—and is higher than the dependable supply in 6 of the 21 water resource regions: the Mid-Atlantic, Texas-Gulf, Missouri Basin, Rio Grande, Lower Colorado, and California.

Overall, withdrawals are expected to increase, but not at the same high rate as in the past. The rate of increase was 11.7% from 1970 to 1975; 19% from 1965 to 1970; and 15% from 1960 to 1965.

In the past, it was common practice to withdraw water for industrial and municipal uses, add wastes, and return the waste water to rivers and streams. Water quality laws now require most industries and municipalities to meet set standards. Many industries are finding it easier and cheaper to recycle water in their plants, thus decreasing the volume withdrawn.

10-12
Water consumption, by use, 1960–1975



Water consumption increased about 25% between 1965 and 1975. Most of the increase came in agriculture as new lands were irrigated for the first time. By the mid-1970s, forty-one million acres of cropland were irrigated. Consumption for industrial uses has also increased as more industries recycle cooling and processing water.

The western States consume more than 12 times more water per capita than the eastern regions, largely because of irrigation.

Consumption exceeded supplies during the 1970s in the Rio Grande and Lower Colorado regions. They imported water from other basins, storing it in Lake Meade, Lake Powell, and other large reservoirs.

Steam electric generation requires large amounts of fresh water but consumes only 2% of what is withdrawn. The 15-year increase in consumption is a function of greater evaporation which results from higher temperatures in cooling water.

10-13

Water withdrawal and consumption in the Pacific Northwest and California regions, 1960-1975

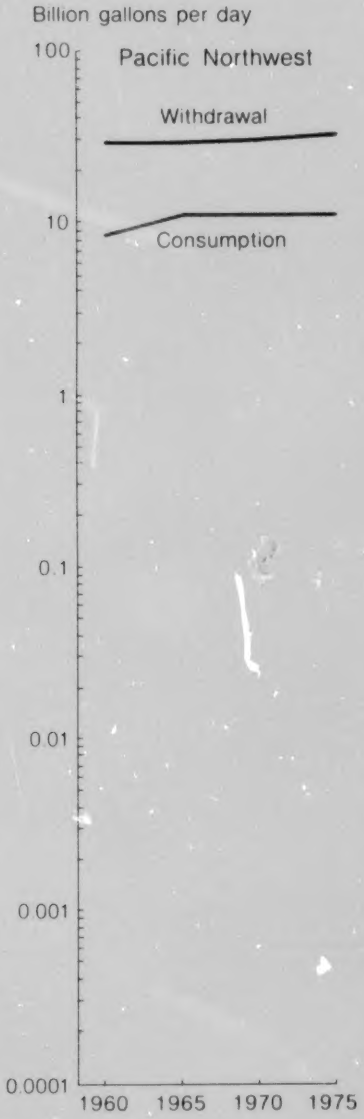
National trends in water supply and demand hide important regional differences. A brief look at the individual regions shows where important water supply and flood problems are or may occur.

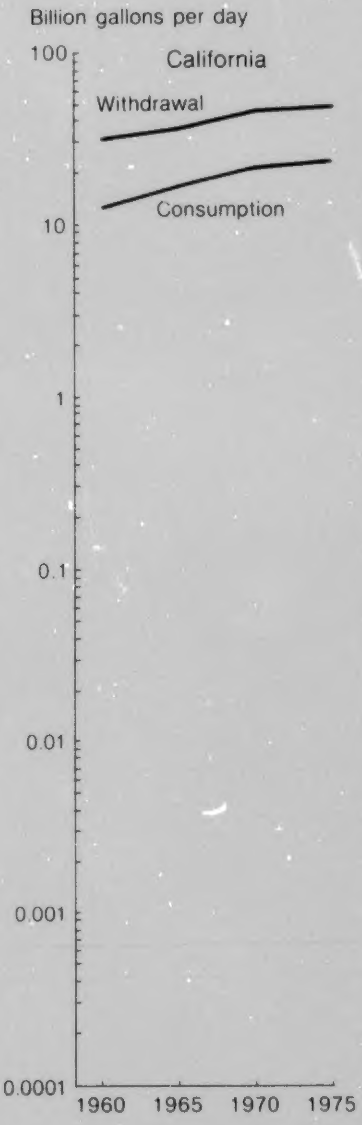
Water supplies are abundant in western Washington and Oregon. East of the Cascades where precipitation is less than in the West, there are seasonal water shortages. Irrigation is the primary offstream user of water.

The major problems with surface water supply in this region are seasonal; for example, irrigation demands conflict with the streamflow needs of the salmon fisheries.

In California, water supplies and population densities are inversely related. The areas of high annual precipitation, up to 100 inches or more, are in the North and the mountains; primary demand for water for agriculture and urban development is in the central valley and southern coastal areas, where precipitation is about 10 inches per year. The discrepancies between supply and demand have been minimized by the massive reservoir storage capacity and conveyance facilities, which are used for irrigation and for domestic and industrial supplies. Some of it is from the Colorado River. In addition, ground water is tapped for irrigation and domestic use.

Pacific Northwest
California


Billion gallons per day
Pacific Northwest
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975


Billion gallons per day
California
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975

10-14

Water withdrawal and consumption in the Great Basin, Upper Colorado, and Lower Colorado regions, 1960–1975

The Colorado River is the life blood of the Southwest. It is the most physically developed and controlled river in the Nation. Half the population of the western States depends at least in part on water supplied by the Colorado River.

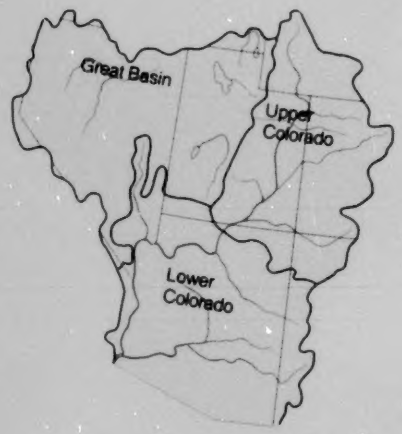
Current use exceeds available renewable supplies, and the difference is being made up by overdraft of ground water, primarily from aquifers in central Arizona and southern Nevada. Fifty-six percent of the water withdrawn in the Lower Colorado region is ground water; half of it is overdraft (2,415 million gallons per day). This area has always been short of surface water. Now ground water is also becoming inadequate.

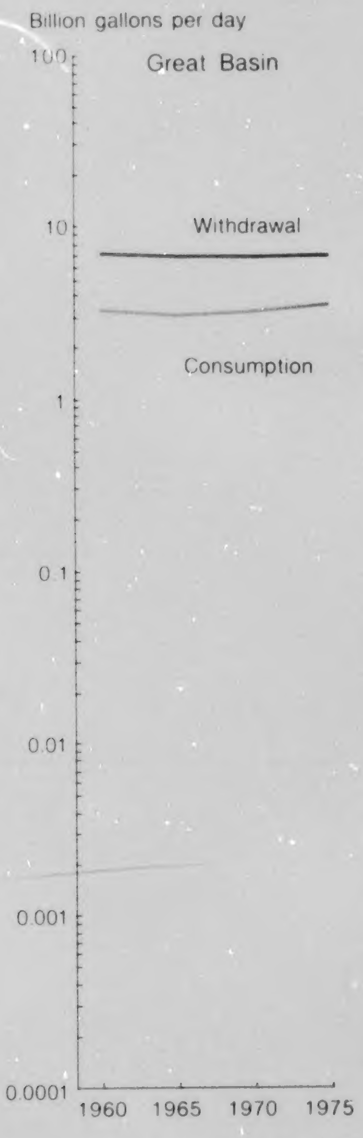
The largest use of water is for irrigation. Almost half the irrigated land in the Lower Colorado region depends entirely on ground water.

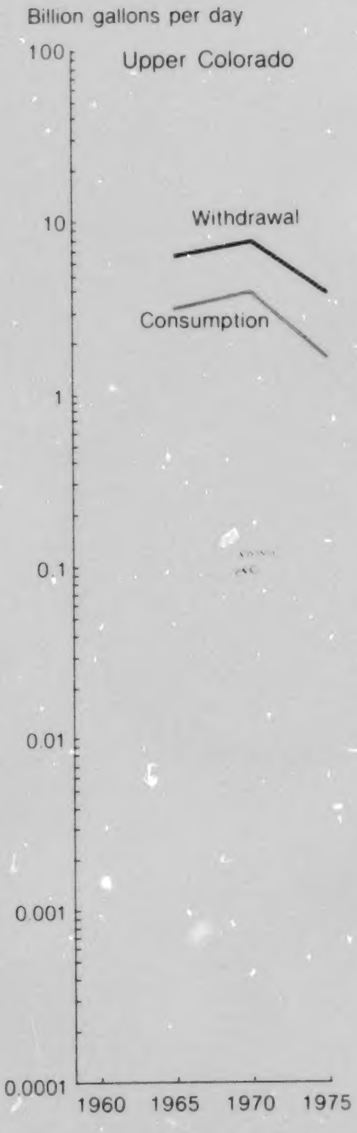
The Colorado River is inadequate to meet regional agricultural, industrial, and municipal requirements. Future demands for water will have to be balanced with conservation or reductions in uses somewhere because available ground water is being depleted. One of the most important demands will be for the mining and processing of coal and oil shale. The extent and timing of such needs are uncertain, but conflicts may be particularly intense in the Upper Colorado region.

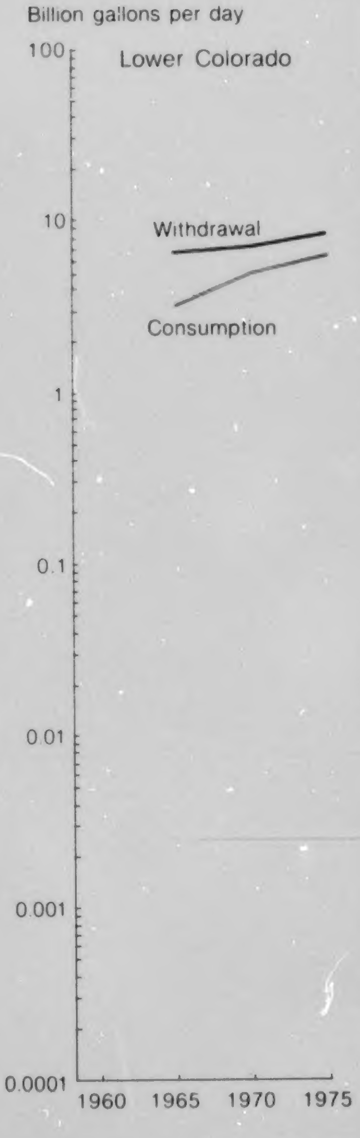
Risk of flooding is becoming a serious problem because new communities are often built on flood plains.

The Great Basin is a hydrologically closed system—that is, all rivers and streams end in terminal lakes or sinks. Irrigation is the largest user of water. Because available water is not sufficient to meet the needs in many areas, it is obtained from other basins. For most development located away from the mountains, ground water supplies are sufficient. Flooding is occasionally serious, particularly in areas of rapid population growth.




Billion gallons per day
Great Basin
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Upper Colorado
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Lower Colorado
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975

10-15

Water withdrawal and consumption in the Missouri, Arkansas-White-Red, Rio Grande, and Texas-Gulf regions, 1960–1975

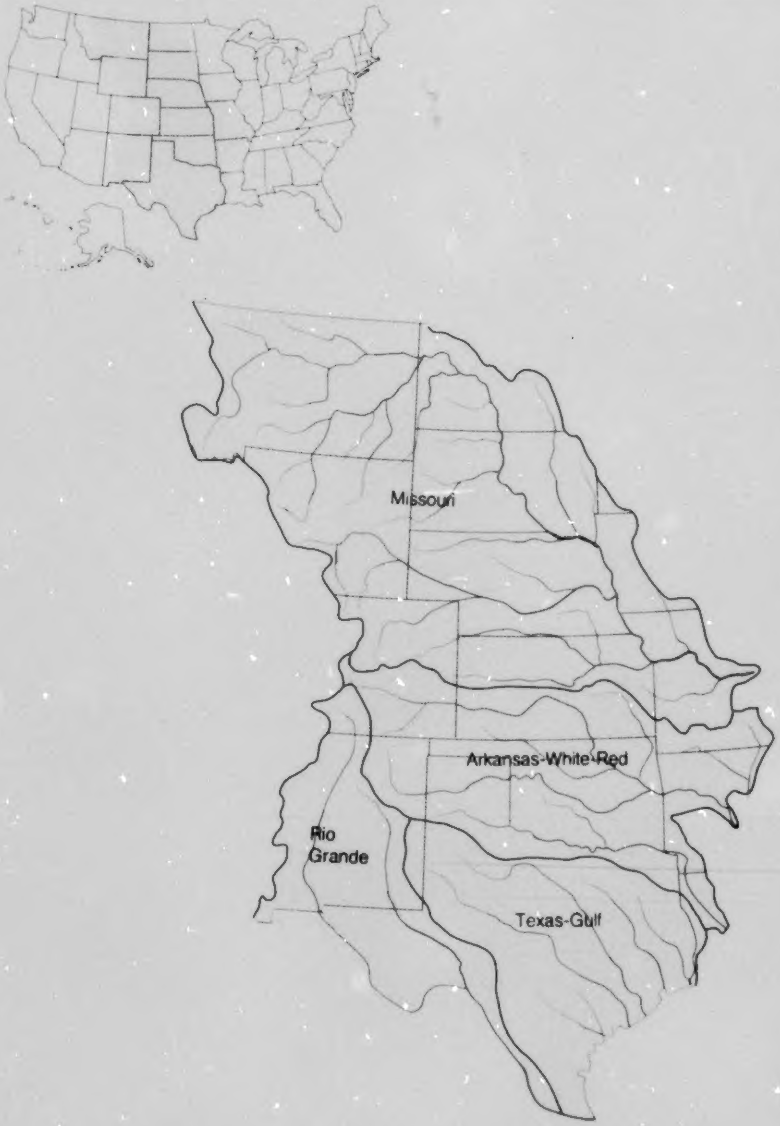
All the rivers in the Northern and Southern Plains drain into the Mississippi River or the Gulf of Mexico. Limited water supplies depend heavily on precipitation, and streamflow in turn depends on ground water seepage because there is relatively little natural surface water.

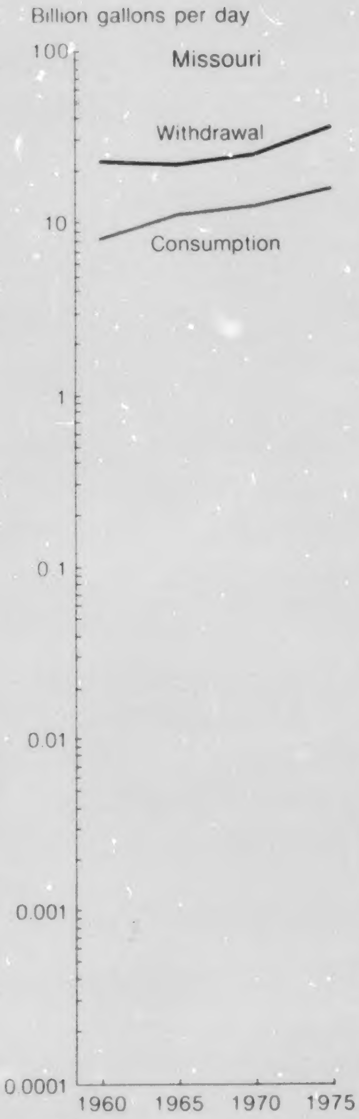
The primary use of water is for irrigation, with consumption for irrigation increasing steadily in the Missouri and Arkansas basins. The Ogallala Formation, a large aquifer system in the Great Plains and Central Lowlands, is being pumped to irrigate 13.1 million acres of farmland in Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas.

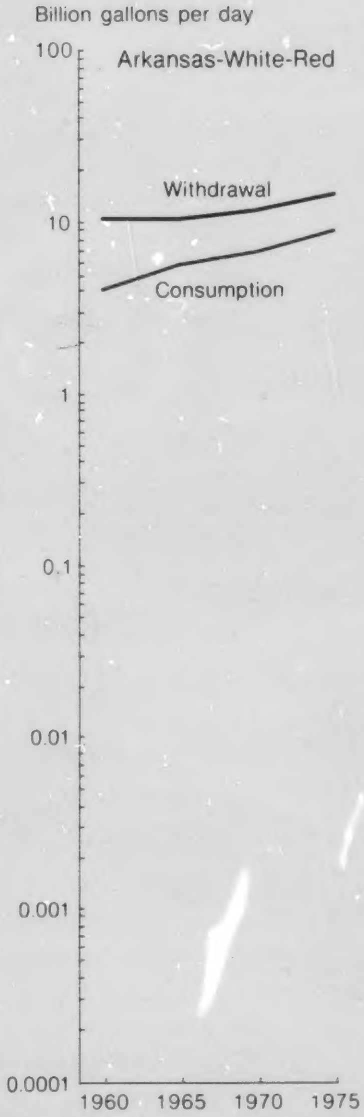
Ground water resources are being rapidly depleted by the overdraft for irrigation. In the Arkansas-White-Red region, for example, 62% of ground water withdrawal is overdraft. If overdrafting continues at current rates, available ground water will be virtually exhausted in 30 to 50 years.

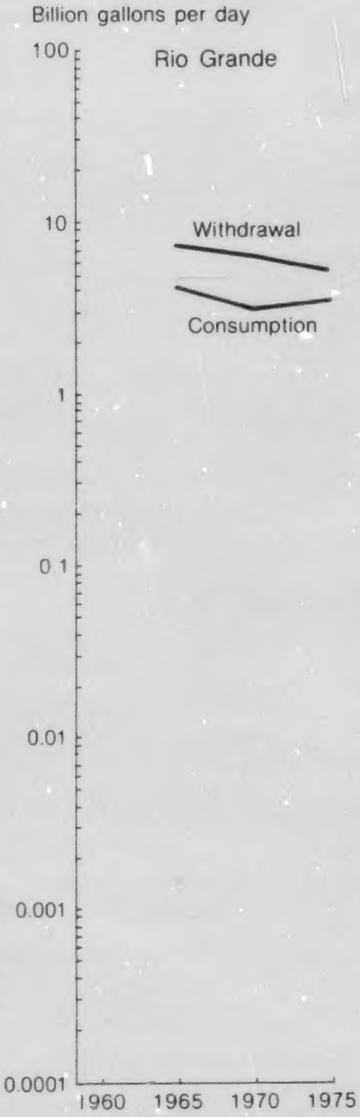
In the Rio Grande region existing surface water is completely appropriated by current demands. Any new demands by an increasing population may have to be met at the expense of irrigation, the largest consumer.

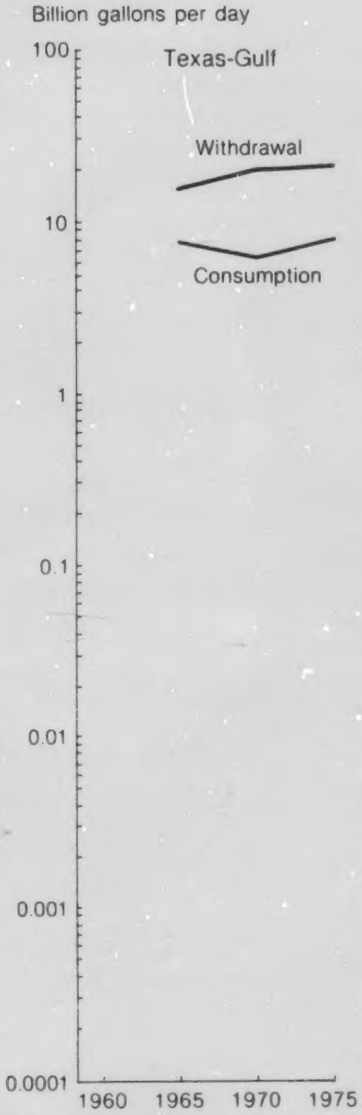
Irrigated cropland is not the only contender for ground water. Rapid population growth and new industry are adding to the demand, particularly in the Texas-Gulf region.




Billion gallons per day
Missouri
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Arkansas-White-Red
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Rio Grande
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Texas-Gulf
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975

386

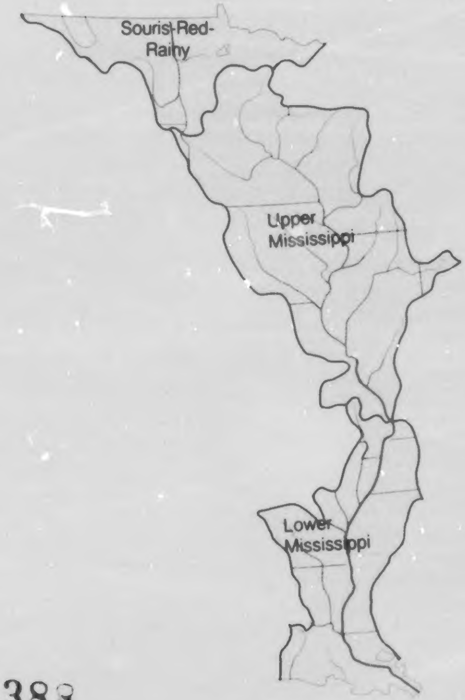
387

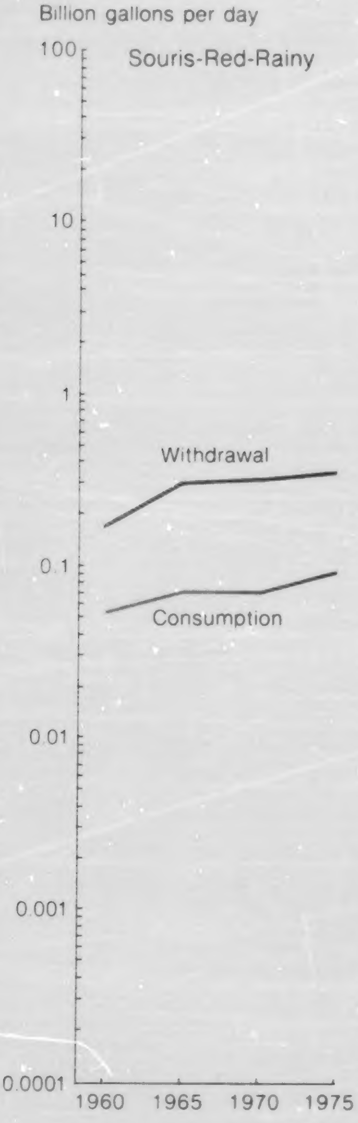
10-16
Water withdrawal and consumption in the Souris-Red-Rainy, Upper Mississippi, and Lower Mississippi regions, 1960–1975

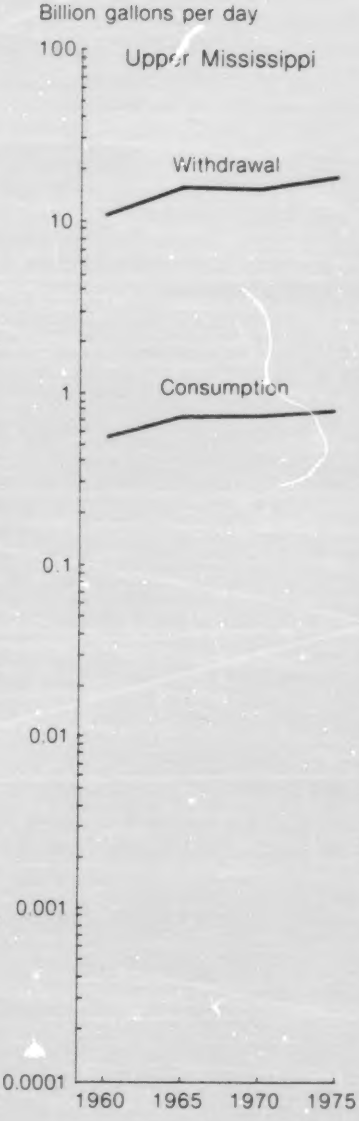
Surface waters of the Souris-Red-Rainy region flow north to Hudson Bay. Water resources are relatively abundant in eastern Minnesota, but during periods of drought in North Dakota, supplies are limited. Major uses are in manufacturing and irrigation.

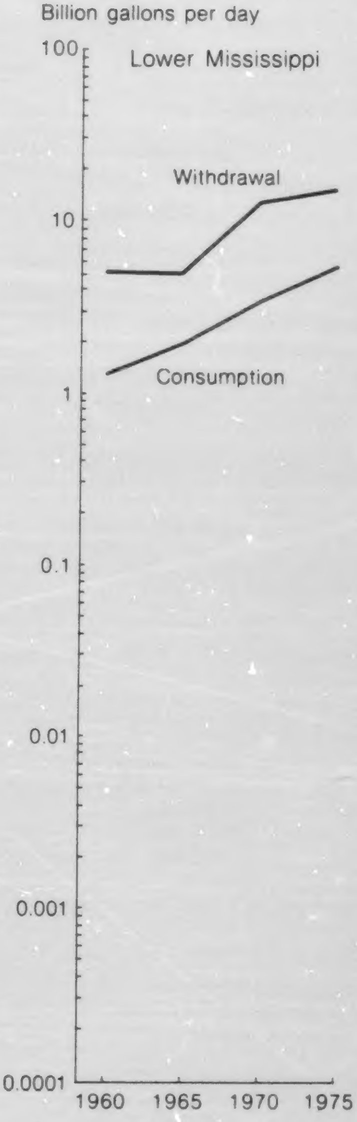
The water supply in the Mississippi regions is sufficient for both instream and offstream uses. All along the Mississippi, major withdrawals are made for steam electric generation. In the Lower Mississippi basin, the amount of water consumed in irrigation has increased rapidly in recent years.

With so much water, the major problem along the Mississippi is flooding. Roughly half the area in the three regions is subject to floods, and one of the most frequently and severely flooded areas is near Memphis.




Billion gallons per day
Souris-Red-Rainy
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Upper Mississippi
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975


Billion gallons per day
Lower Mississippi
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975

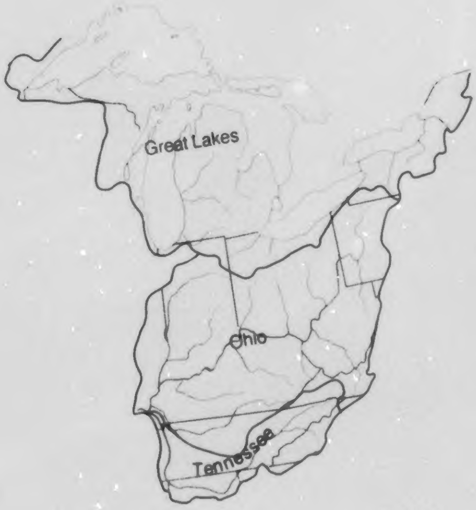
10-17

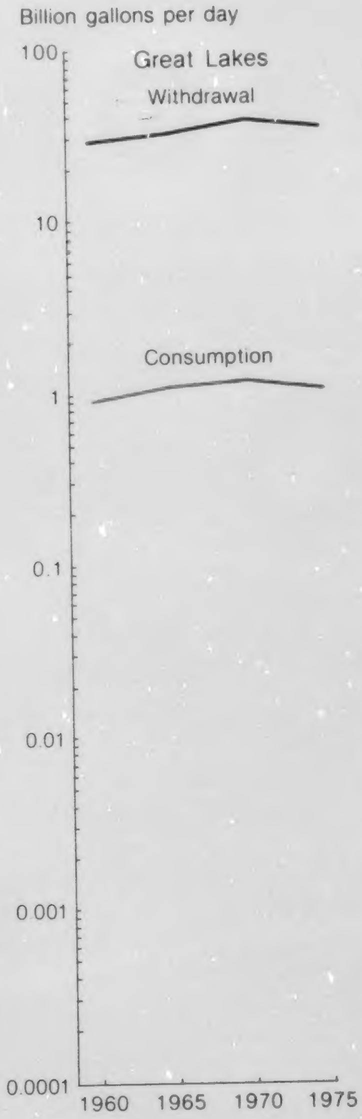
Water withdrawal and consumption in the Great Lakes, Ohio, and Tennessee regions, 1960–1975

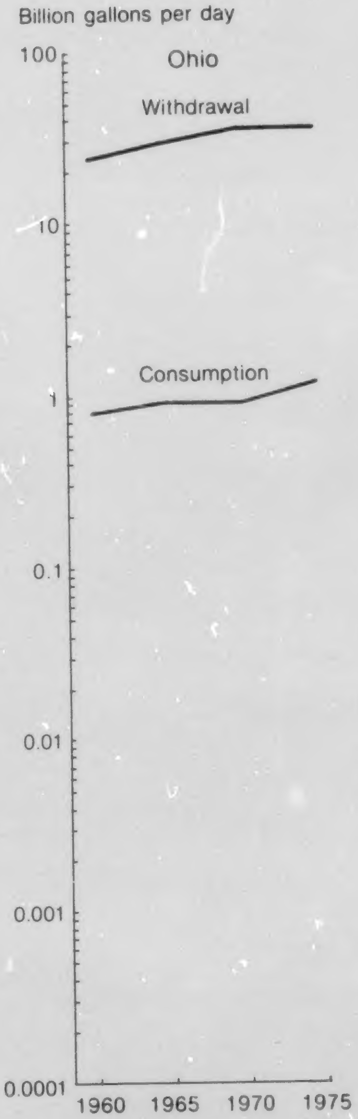
Like the regions bordering the Atlantic, the Great Lakes region and the areas immediately west of the Appalachians generally have ample water resources. Both surface and ground waters are abundant, except for serious ground water depletion in local areas of northern Michigan and Wisconsin and in parts of Minnesota.

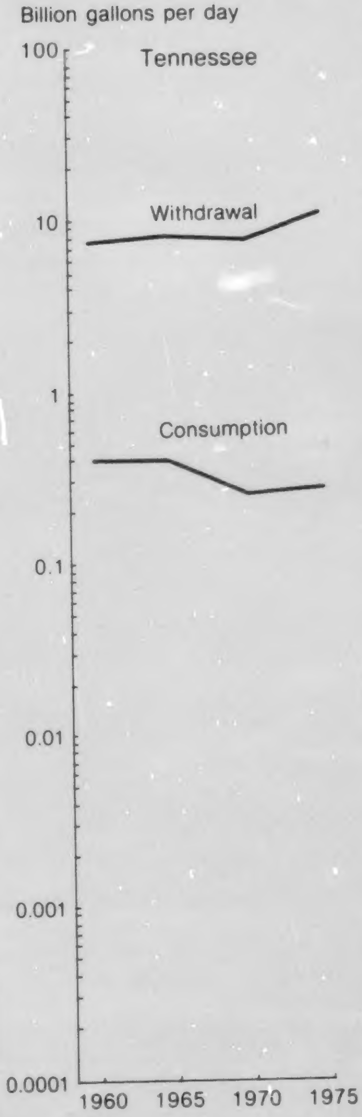
Water is withdrawn primarily for steam electric generation and manufacturing. Major instream uses are navigation on the Great Lakes and the Ohio River and hydropower, navigation, and recreation on the Tennessee River.

Flooding is serious in all three regions but is particularly severe in the headwaters of the Tennessee River, where the rugged terrain encourages building in the flood plains. By far the most serious water problem in the region is water quality.




Billion gallons per day
Great Lakes
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975


Billion gallons per day
Ohio
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975


Billion gallons per day
Tennessee
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975

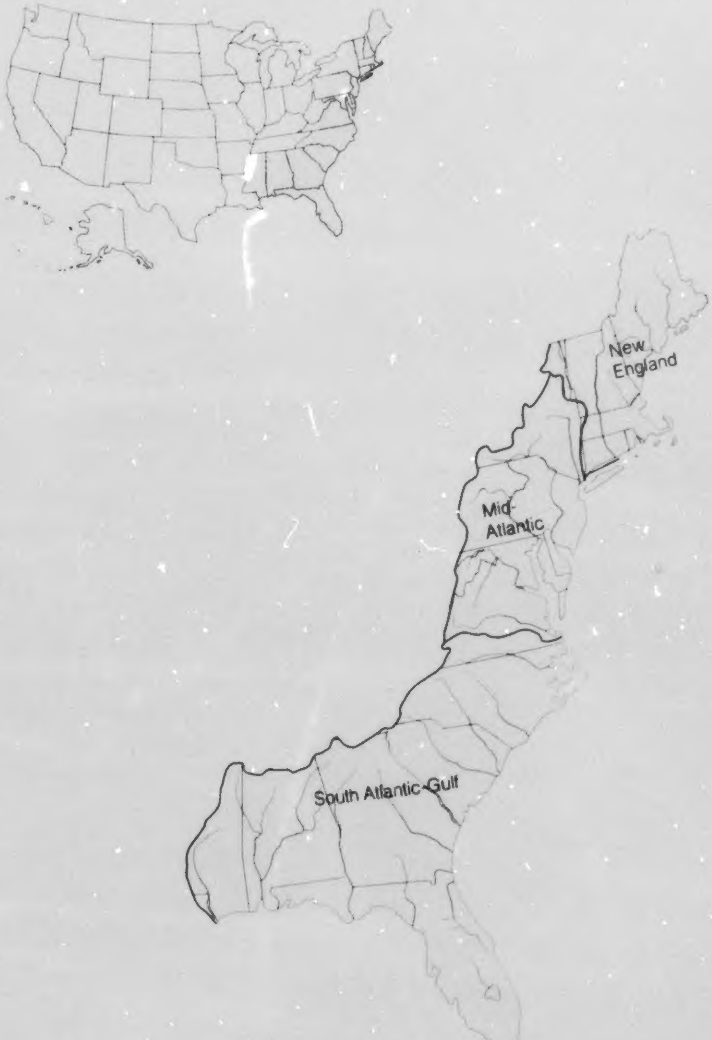
10-18

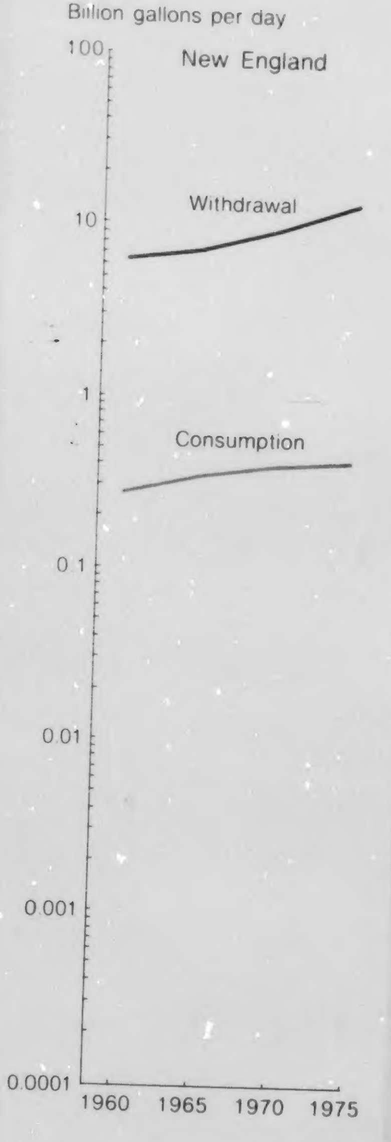
Water withdrawal and consumption in the New England, Mid-Atlantic, and South Atlantic-Gulf regions, 1960–1975

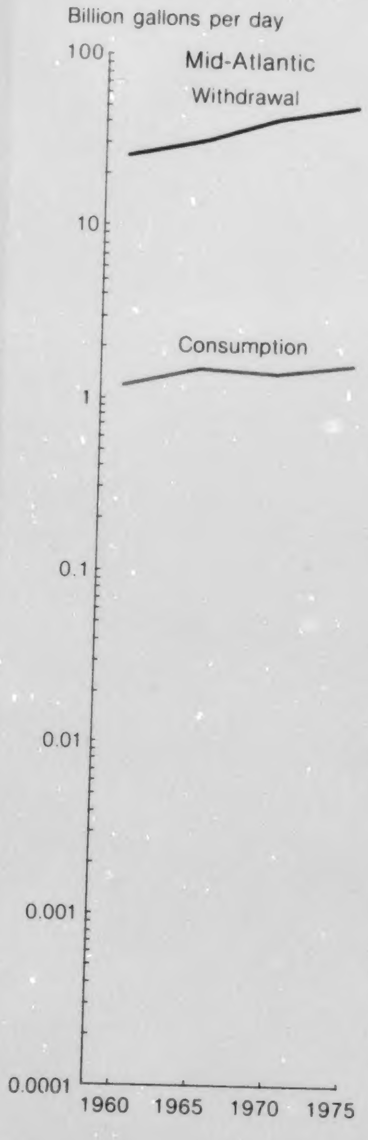
Water is generally abundant along the Atlantic coast. Supply problems exist in urban coastal areas of Massachusetts and Connecticut and in the metropolitan areas of New York City and northern New Jersey because of domestic, steam electric, and industrial demands. In the southern coastal areas where intrusion of saline ground water limits ground water withdrawals, some types of development are also limited.

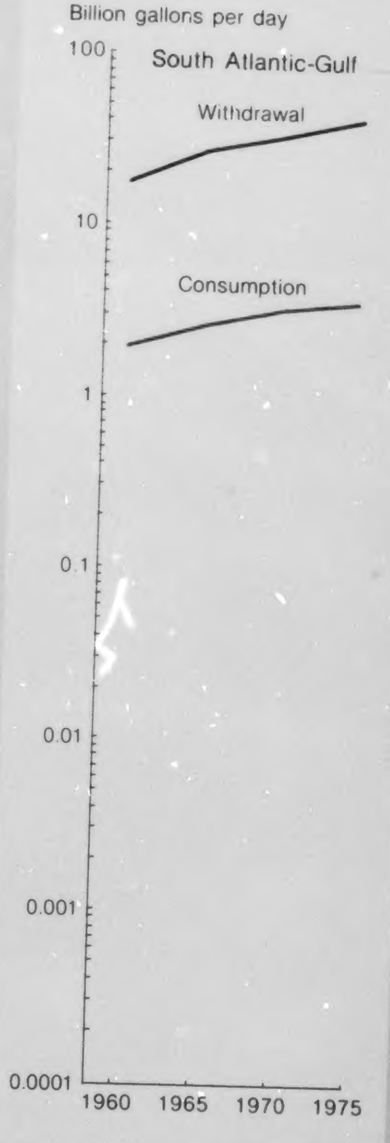
In the New England and Mid-Atlantic regions, the largest withdrawals are for industry and steam electric plants. In the South Atlantic-Gulf region, the paper and pulp industry is responsible for the large withdrawals.

In the New England and Mid-Atlantic regions, flooding is a major problem, with substantial risk to life and property as a result of extensive residential and commercial development in flood plain areas.




Billion gallons per day
New England
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975


Billion gallons per day
Mid-Atlantic
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975


Billion gallons per day
South Atlantic-Gulf
Withdrawal
Consumption
100
10
1
0.1
0.01
0.001
0.0001
1960
1965
1970
1975

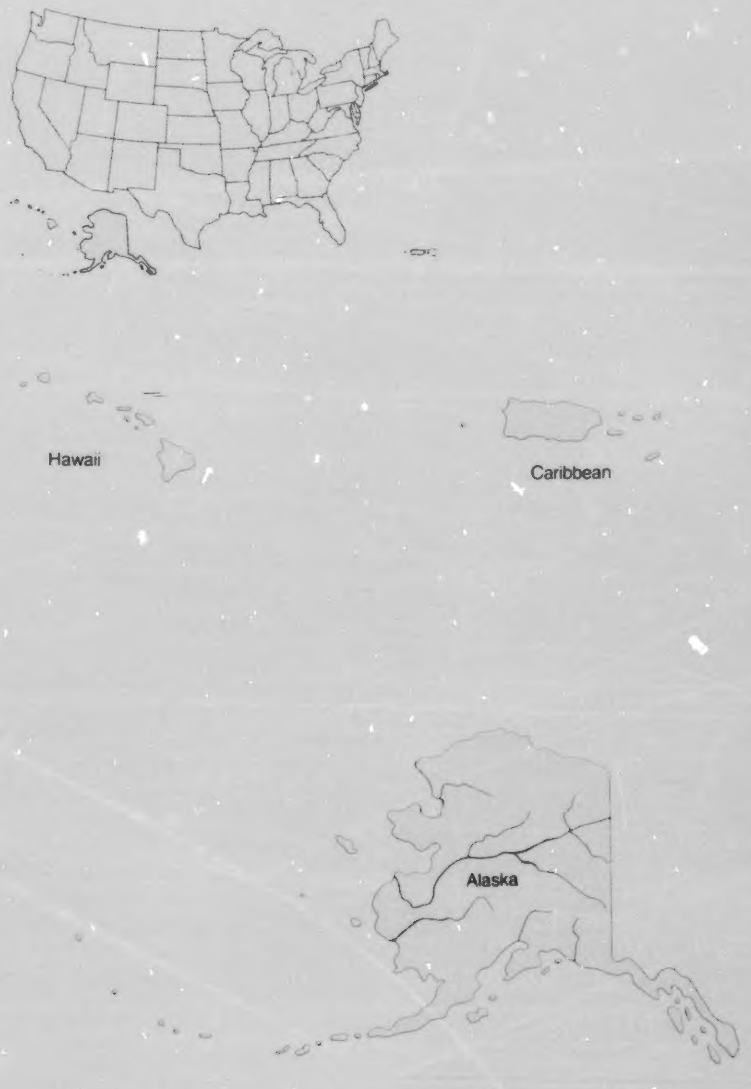
10-19

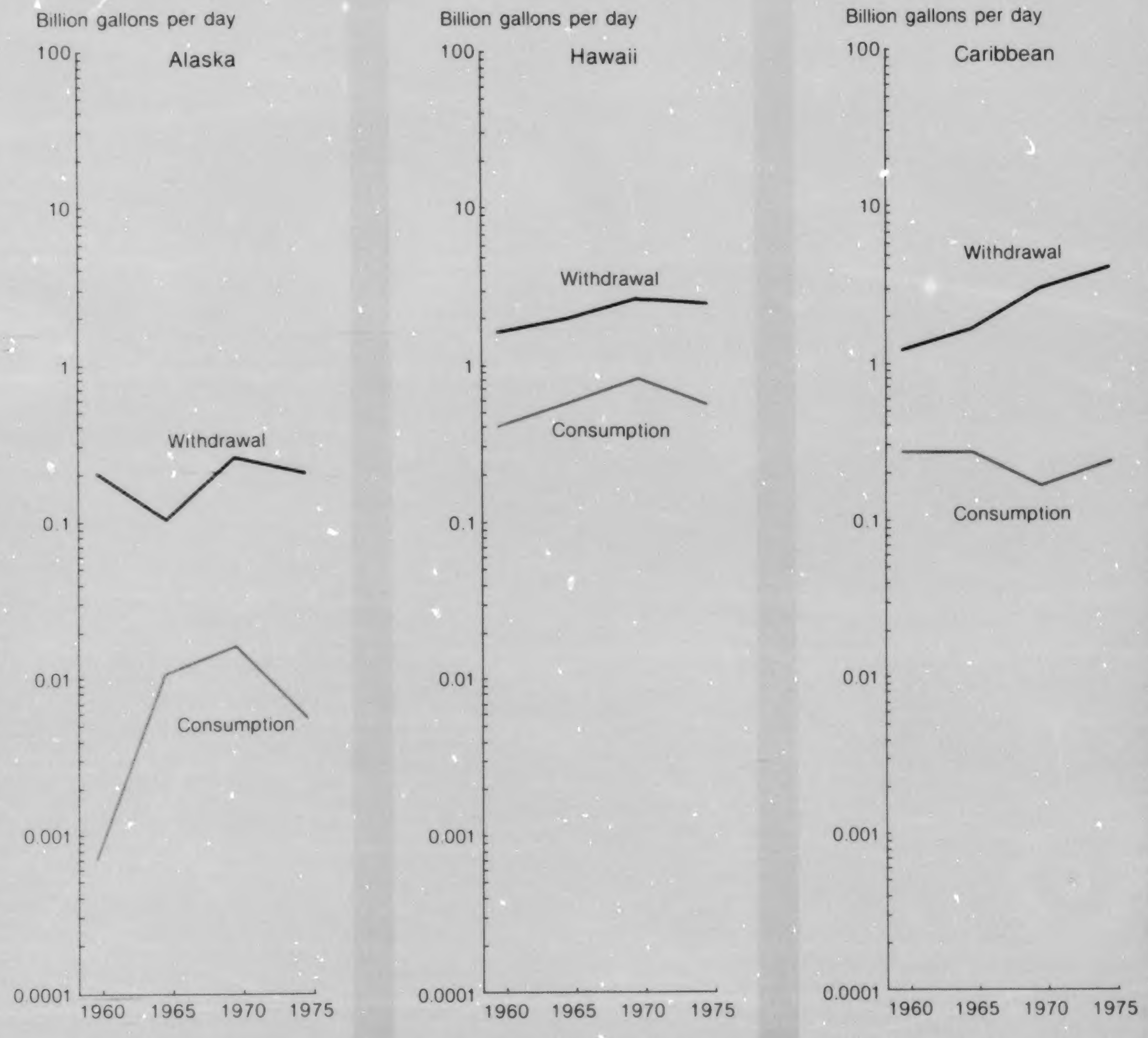
Water withdrawal and consumption in Alaska, Hawaii, and Caribbean regions, 1960–1975

A third of the Nation's fresh water is in Alaska. The primary offstream use is for manufacturing and mining. Instream uses include sport and commercial fishing and maintenance of extensive wetland wildlife habitat.

Rainfall in Hawaii is able to supply most foreseeable water needs. The primary offstream use of water is for irrigation.

Water supplies are ample in Puerto Rico but are severely limited in the Virgin Islands because of low rainfall and the mountainous terrain. Irrigation is the largest user.




Billion gallons per day
Alaska
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975
Billion gallons per day
Hawaii
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975
Billion gallons per day
Caribbean
100
10
1
0.1
0.01
0.001
0.0001
Withdrawal
Consumption
1960
1965
1970
1975

Sources and technical notes

U.S. Water Resources Council data for 1975 refers to a mid-1970s period rather than to the specific year. It is the base period for 1985 and 2000 projections for the Second National Water Assessment by the Water Resources Council.

10-1
The hydrologic cycle

Adapted from "Where we get our water: From ocean to sky to land to ocean," W. C. Ackerman, E. A. Coleman, and H. O. Ogrosky, in "Water," *The yearbook of agriculture 1955*, U.S. Department of Agriculture (Washington: USGPO, 1955), p. 42.

10-2
Water resource regions, 1975

The nation's water resources, 1975–2000, U.S. Water Resources Council (Washington: USGPO, 1978), v. 1, summary, p. 5.

The United States is divided into 21 hydrologic regions, each with a major river basin or a series of smaller river basins. These regions are divided into 106 assessment subregions and 222 planning subregions. For each region, approximate county areas are designated for comparison of demand and use data with supply data.

Inland water surfaces include lakes, reservoirs, and ponds having 40 acres or more area; streams, sloughs, estuaries, and canals one-eighth of a statute mile or more in width; and deeply indented embayments and sounds and other coastal waters behind or sheltered by headlands or islands separated by less than 40 acres of area.

10-3
Average annual precipitation, 1931–1960

See 10-2, p. 16.

The world average includes 26 inches of rain and 9 inches of snow, sleet, or hail.

10-4
Available ground water, 1975

The nation's water resources, 1975–2000, U.S. Water Resources Council, (Washington: USGPO, 1978), v. 3 (analytic data), appendix II (annual water supply and use analysis), table II-1, pp. 23–26.

10-5
Ground water withdrawal, 1975

"Annual water adequacy analysis," U.S. Water Resources Council, unpublished computer printout, August 1979, prepared for the Water Resources Council Second National Water Assessment, table ZI-5.

10-6
Ground water overdraft, 1975

See 10-4.

10-7
Average streamflow of large rivers, 1941–1970

Large rivers of the United States, K. T. Iseri and W. B. Langbein, U.S. Geological Survey (Washington: USGPO, 1975), circ. 686, p. 4.

10-8
Inadequate surface water supply for instream use, 1975

The nation's water resources, 1975–2000, U.S. Water Resources Council (Washington: USGPO, 1978), v. 2 (water quantity, quality, and related land considerations), part II (water-management problem profiles), table II-7, pp. 138–147.

10-9
Flooding problems, 1975

Estimated flood damages, U.S. Water Resources Council (Washington: USGPO, 1977), appendix B, nationwide analysis report, p. 13.

Degree of severity is based on dollar losses and damages—current, projected, percent increase projected between 1975 and 2000, per person, per earnings, per unit area, and cropland losses—and on the number of places in a subregion with flooding problems.

10-10
Water use, 1900–1975

Withdrawals, 1900–1970, and consumption, 1960–1970: *Water policies for the future*, National Water Commission (Port Washington, N.Y.: Water Information Center, Inc., 1973), p. 7.

Withdrawals and consumption, 1975: *Estimated use of water in the United States in 1975*, U.S. Geological Survey (Washington: USGPO, 1977), circ. 765, p. 10.

If water is returned to a surface water source and is again withdrawn, it is again counted in total withdrawals.

10-11
Water withdrawal, by use, 1950–1975

1950–1970: *Estimated use of water in the United States in 1970*, U.S. Geological Survey (Washington: USGPO, 1972), circ. 676, p. 10.

1975: *Estimated use of water in the United States in 1975*, U.S. Geological Survey (Washington: USGPO, 1977), circ. 765, p. 10.

10-12
Water consumption, by use, 1960–1975

1960: *Estimated use of water in the United States, 1960*, U.S. Geological Survey (Washington: USGPO, 1961), circ. 456, tables 1, 3, 5, 7, 9, 15, pp. 13, 15, 17, 19, 21, 24.

1965: *Estimated use of water in the United States, 1965* (Washington: USGPO, 1968), circ. 556, tables 5, 8, 11, 14, 17, 26, pp. 17, 22, 26, 33, 39, 47.

1970: *Estimated use of water in the United States in 1970* (Washington: USGPO, 1972), circ. 676, tables 5, 6, 7, 8, 9, 10, pp. 19, 21, 23, 25, 27, 29.

1975: *Estimated use of water in the United States in 1975* (Washington: USGPO, 1977), circ. 765, tables 5, 6, 7, 8, 9, 10, pp. 21, 23, 25, 27, 29, 31.

10-13 through 10-19
Water withdrawal and consumption, by region, 1960–1975

1960: *Estimated use of water in the United States, 1960*, U.S. Geological Survey (Washington: USGPO, 1961), circ. 456, p. 25.

1965: *Estimated use of water in the United States, 1965* (Washington: USGPO, 1968), circ. 556, pp. 48, 49.

1970: *Estimated use of water in the United States in 1970* (Washington: USGPO, 1972), circ. 676, pp. 28, 36.

1975: *Estimated use of water in the United States in 1975* (Washington: USGPO, 1977), circ. 765, p. 38.

For additional discussion of water resources see the 21 regional reports in *The nation's water resources, 1975–2000*, U.S. Water Resources Council (Washington: USGPO, 1978), v. 4.

Chapter 11

Water Quality

Ideally, water quality would be measured in terms of its impacts on all living systems, human and other. But because measuring the functions of biological systems is difficult, water quality is described by the extent to which lakes, rivers, and streams can physically, biologically, and chemically support aquatic life and meet the standards recommended for human use.

Efforts to keep water clean or to restore it to a healthy state center on controlling the amounts and kinds of materials that are dumped or washed into waterways, the ground, and the air. Water quality of rivers, lakes, and oceans depends upon their individual capacity to handle a given pollutant. In turn, the capacity varies with the type and amount of the pollutant; water temperature, flow, and sediment; and mineral content.

Under Federal law, the Government is directed to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters"—to eliminate the discharge of pollutants by 1985; to maintain water quality that protects fish, shellfish, and wildlife, and provides for recreational use by 1983; and to prohibit the discharge of toxic substances in amounts that are toxic to humans and wildlife.

Control of pollutants discharged directly from industrial and municipal sources (point sources) into waterways is progressing, but little progress has been made in the kinds and amounts of materials that enter waterways from erosion, urban runoff, and many other general sources (nonpoint sources).

11-1

Sources and effects of water pollutants

Wastes that degrade water quality range from the primarily organic disease-carrying agents in human and animal wastes to inorganic materials and minerals to radioactive materials and heat. All can seriously degrade the quality of water, can harm aquatic life, and can limit recreational and other uses.

Sources:

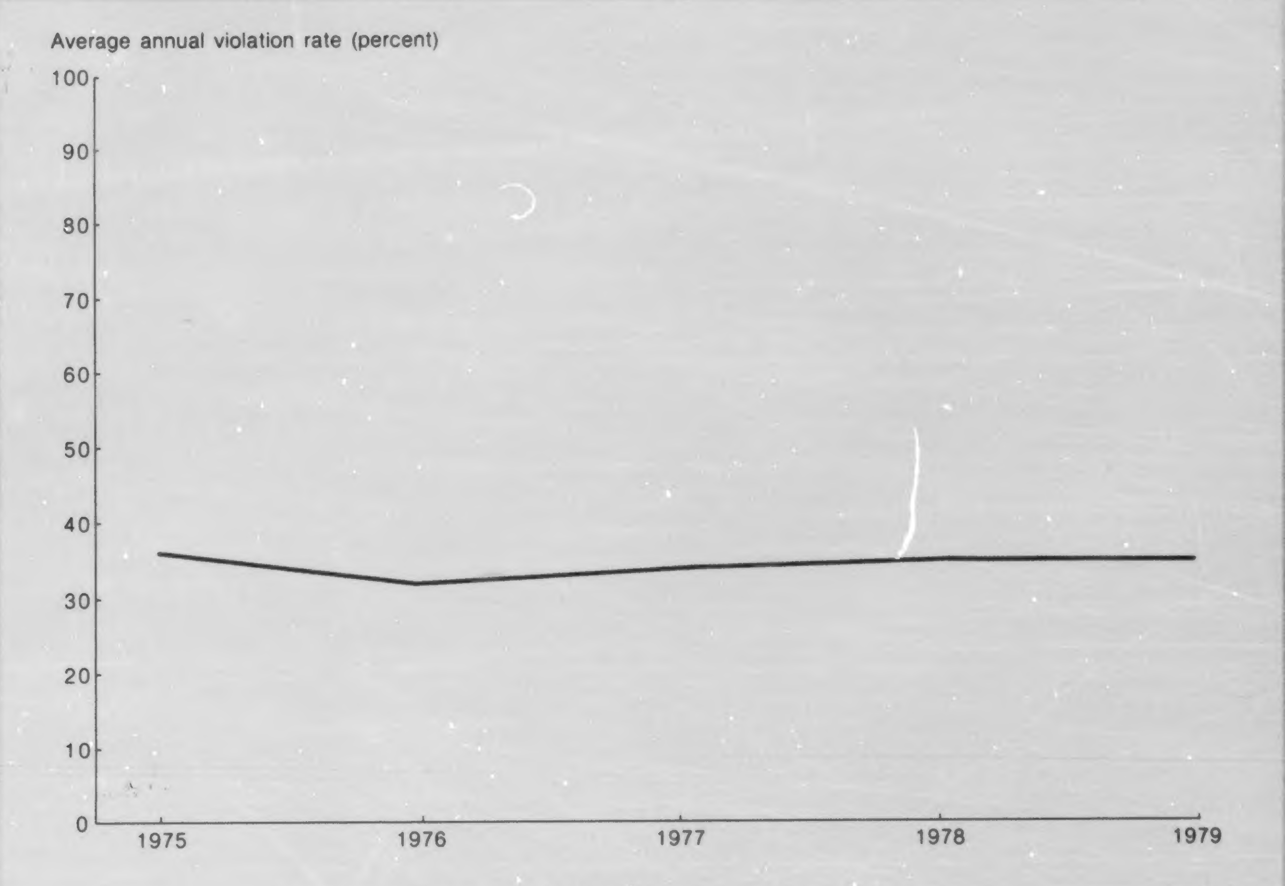
Based on "The future of the Nation's waters," W.O. Pipes (Drexel University, 1976), table 2; *Environmental Quality—1979*, Council on Environmental Quality (Washington: USGPO, 1979), and previous annual reports.

Type of waste	Wastewater sources	Water quality measures	Effects on water quality	Effects on aquatic life	Effects on recreation
Disease-carrying agents--human feces, warm-blooded animal feces	Municipal discharges, watercraft discharges, urban runoff, agricultural runoff, feedlot wastes, combined sewer overflows, industrial discharges	Fecal coliform, fecal streptococcus, other microbes	Health hazard for human consumption and contact	Inedibility of shellfish for humans	Reduced contact recreation
Oxygen-demanding wastes--high concentrations of biodegradable organic matter	Municipal discharges, industrial discharges, combined sewer overflows, watercraft discharges, urban runoff, agricultural runoff, feedlot wastes, natural sources	Biochemical oxygen demand, dissolved oxygen, volatile solids, sulfides	Deoxygenation, potential for septic conditions	Fish kills	If severe, eliminated recreation
Suspended organic and inorganic material	Mining discharges, municipal discharges, industrial discharges, construction runoff, agricultural runoff, urban runoff, silvicultural runoff, natural sources, combined sewer overflows	Suspended solids, turbidity, biochemical oxygen demand, sulfides	Reduced light penetration, deposition on bottom, benthic deoxygenation	Reduced photosynthesis, changed bottom organism population, reduced fish production, reduced sport fish population, increased non-sport fish population	Reduced game fishing, aesthetic appreciation
Inorganic materials, mineral substances--metal, salts, acids, solid matter, other chemicals, oil	Mining discharges, acid mine drainage, industrial discharges, municipal discharges, combined sewer overflows, urban runoff, oil fields, agricultural runoff, irrigation return flow, natural sources, cooling tower blowdown, transportation spills, coal gasification	pH, acidity, alkalinity, dissolved solids, chlorides, sulfates, sodium, specific metals, toxicity bioassay, visual (oil spills)	Acidity, salination, toxicity of heavy metals, floating oils	Reduced biological productivity, reduced flow, fish kills, reduced production, tainted fish	Reduced recreational use, fishing, aesthetic appreciation
Synthetic organic chemicals--dissolved organic material, e.g., detergents, household aids, pesticides	Industrial discharges, urban runoff, municipal discharges, combined sewer overflow, agricultural runoff, silvicultural runoff, transportation spills, mining discharges	Cyanides, phenols, toxicity bioassay	Toxicity of natural organics, biodegradable or persistent synthetic organics	Fish kills, tainted fish, reduced reproduction, skeletal development	Reduced fishing, inedible fish for humans
Nutrients--nitrogen, phosphorus	Municipal discharges, agricultural runoff, combined sewer overflows, industrial discharges, urban runoff, natural sources	Nitrogen, phosphorus	Increased algal growth, dissolved oxygen reduction	Increased production, reduced sport fish population, increased non-sport fish population	Tainted drinking water, reduced fishing and aesthetic appreciation
Radioactive materials	Industrial discharges, mining	Radioactivity	Increased radioactivity	Altered natural rate of genetic mutation	Reduced opportunities
Heat	Cooling water discharges, industrial discharges, municipal discharges, cooling tower blowdown	Temperature	Increased temperature, reduced capacity to absorb oxygen	Fish kills, altered species composition	Possible increased sport fishing by extended season for fish which might otherwise migrate

Rivers and streams

The 3 million miles of rivers and streams in the United States have offered a convenient dumping ground for industrial and municipal wastes and are the natural catchall for land runoff. Most of the cleanup efforts by government and industry, then, focus on rivers and streams.

11-2
Fecal coliform bacteria, average annual violation rates, 1975–1979

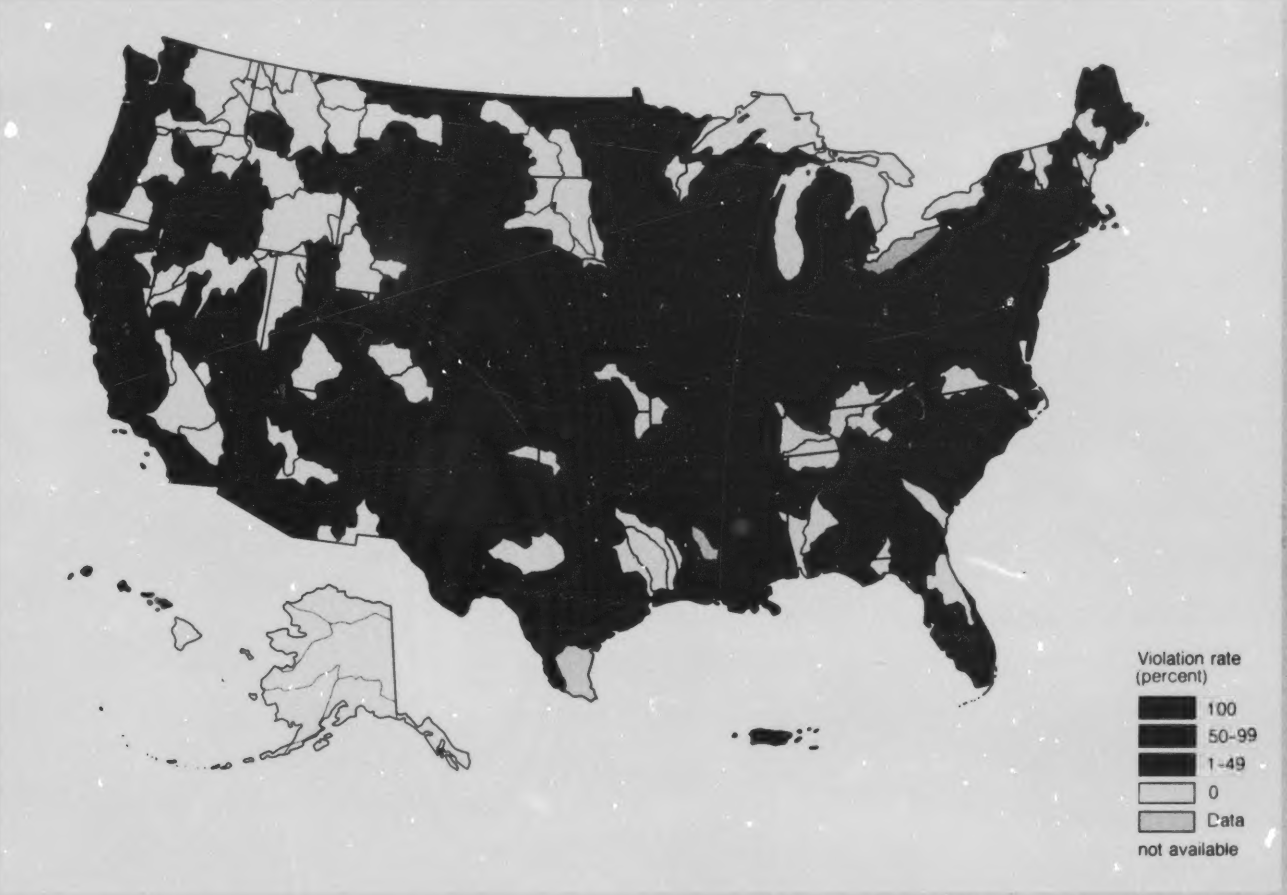


One measure of water quality is fecal coliform bacteria, which indicates the presence of untreated fecal matter from humans and other warm-blooded animals. Fecal coliform bacteria are not generally harmful, but they indicate the possible presence of infectious microorganisms that cause typhoid fever, viral hepatitis, tuberculosis, and encephalitis.

The threshold level for fecal coliform bacteria set to protect human health in waters used for swimming is 200 cells per 100 milliliters of water. The average annual violation rate in 1979 was 35%—that is, in 35% of all measurements taken, fecal coliform levels exceeded the nationally recommended level.

11-3
Fecal coliform bacteria in U.S. waters, 1978

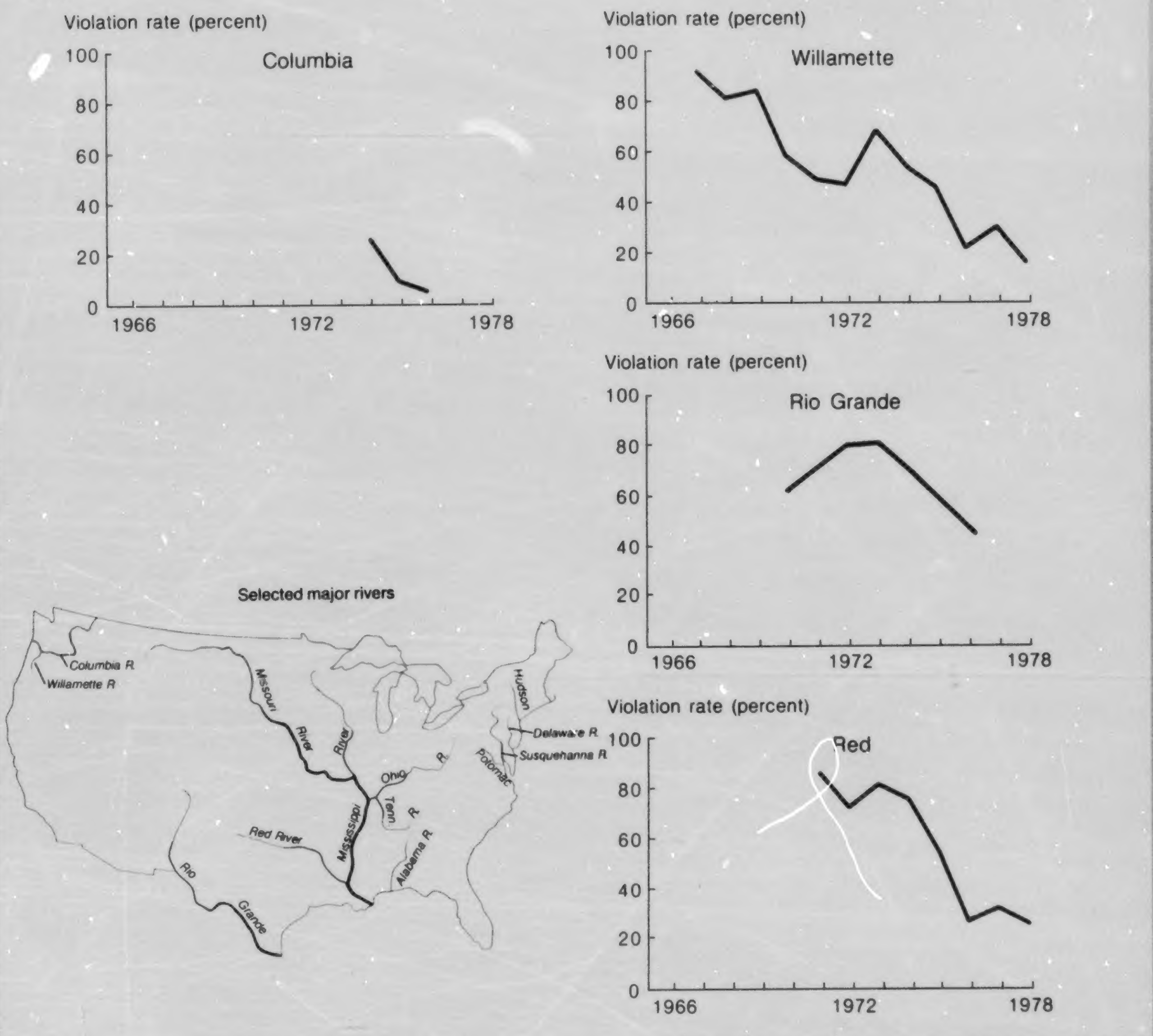
There were two water basins with high fecal coliform violation rates from 1975 to 1978—the Ohio, with 4 of its 21 accounting units at 90% or above, and the Missouri, with 3 of its 45 accounting units at 100% violation.


Violation rate (percent)
■ 100
■ 50-99
■ 1-49
□ 0
▨ Data not available

NASQAN Monitoring Stations

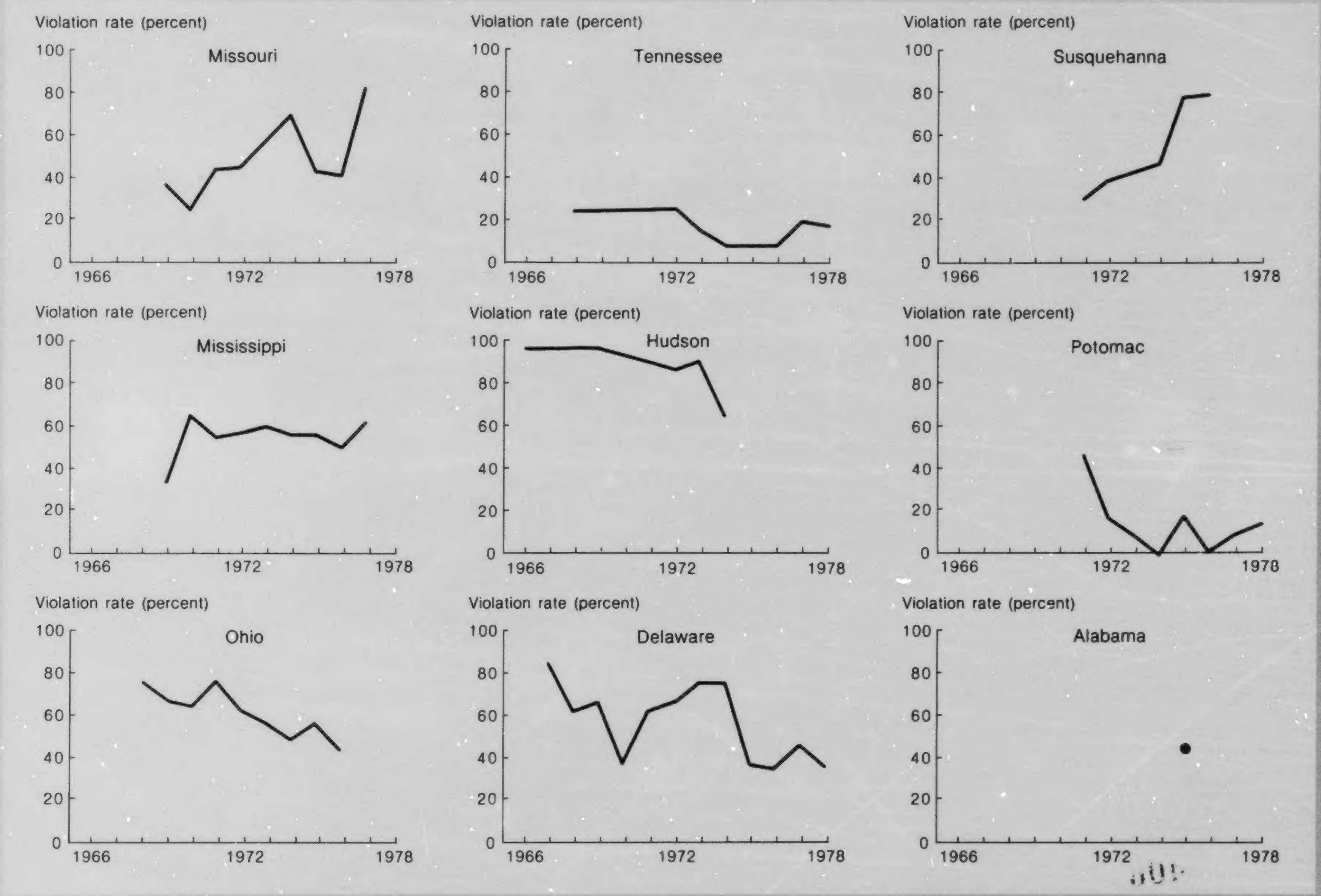
11-4
Fecal coliform bacteria in major rivers, 1966–1978

In many large rivers, fecal coliform bacteria levels are declining. The Willamette and Red rivers have shown the most improvement. Violations for the Mississippi, Missouri, Hudson, and Susquehanna continue above 50%.



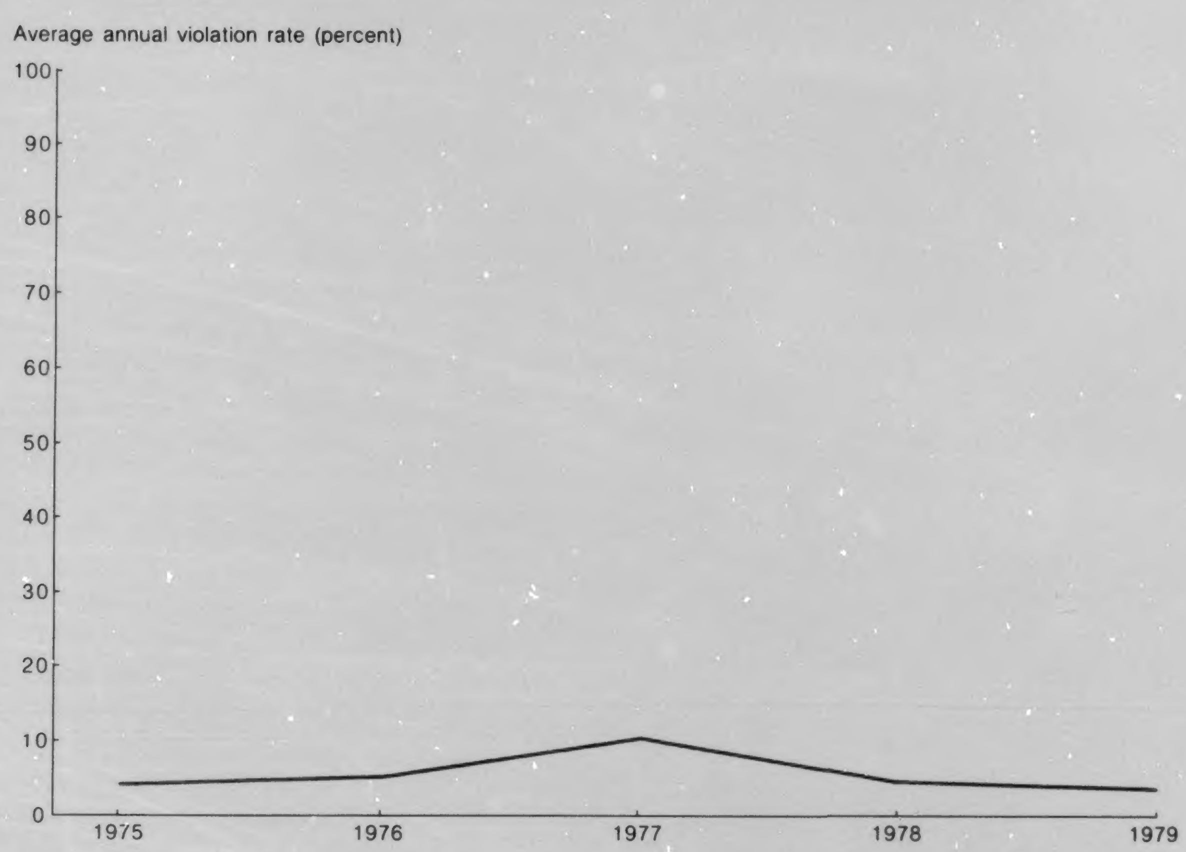
406

407


Violation rate (percent)
Missouri
Violation rate (percent)
Tennessee
Violation rate (percent)
Susquehanna
Violation rate (percent)
Mississippi
Violation rate (percent)
Hudson
Violation rate (percent)
Potomac
Violation rate (percent)
Ohio
Violation rate (percent)
Delaware
Violation rate (percent)
Alabama
0
20
40
60
80
100
1966
1972
1978

11-5

Dissolved oxygen, average annual violation rates, 1975–1979



The amount of dissolved oxygen in water determines the extent to which the water body can support aquatic organisms which use dissolved oxygen to metabolize food. The oxygen that is naturally dissolved in water is used when a substance is oxidized in water. Decaying leaves, soil, organic matter, and animal fecal matter also deplete oxygen levels. So do agricultural feedlot and topsoil runoff, municipal sewage, and a wide variety of materials discharged directly into the water by industry. It is the extra load of manmade wastes that most often depletes dissolved oxygen, upon which aquatic life depends.

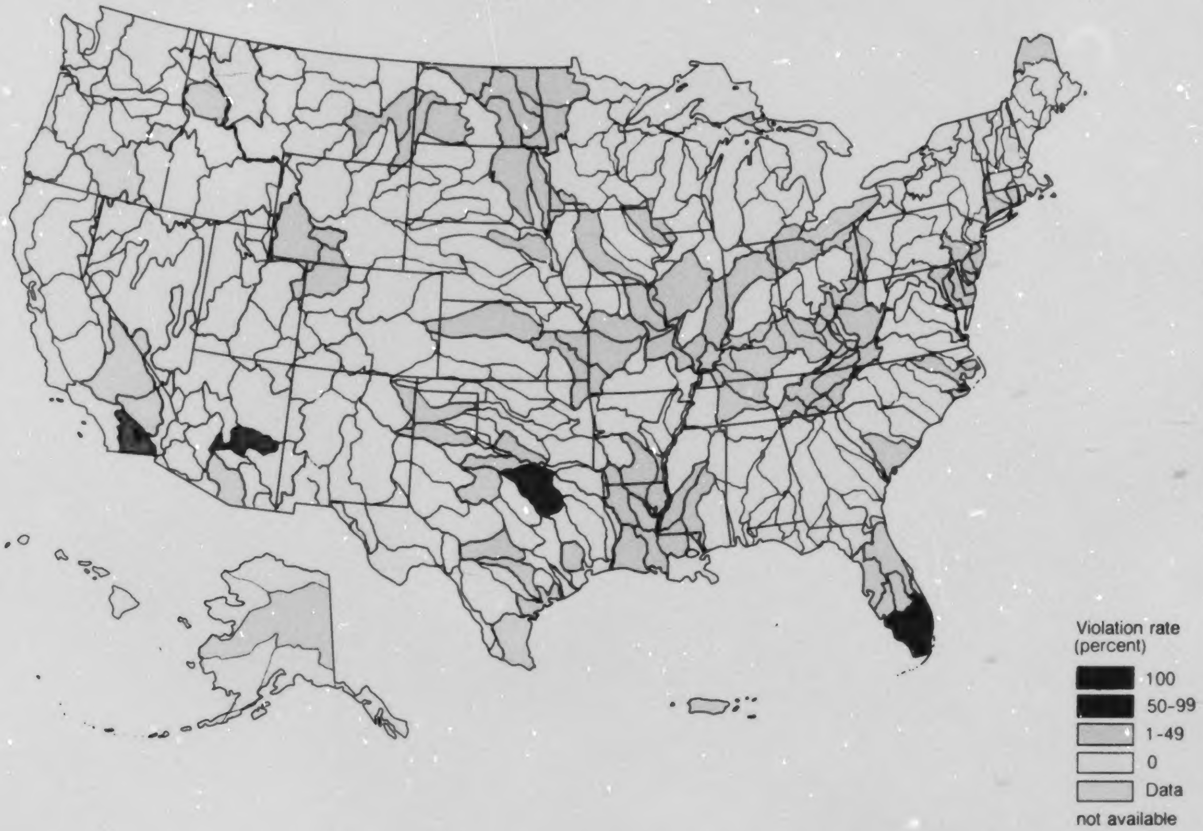
The criterion for dissolved oxygen set to sustain many forms of aquatic life is 5 milligrams per liter of water.

The average annual violation rate for dissolved oxygen in 1979 was 4%—that is, in 4% of all measurements taken, dissolved oxygen levels exceeded the nationally recommended level.

A violation of the acceptable oxygen level is more severe than other violations of ambient conditions because it means that many forms of aquatic life cannot live. Smaller streams are particularly prone to this problem.

11-6

Dissolved oxygen in U.S. waters, 1978

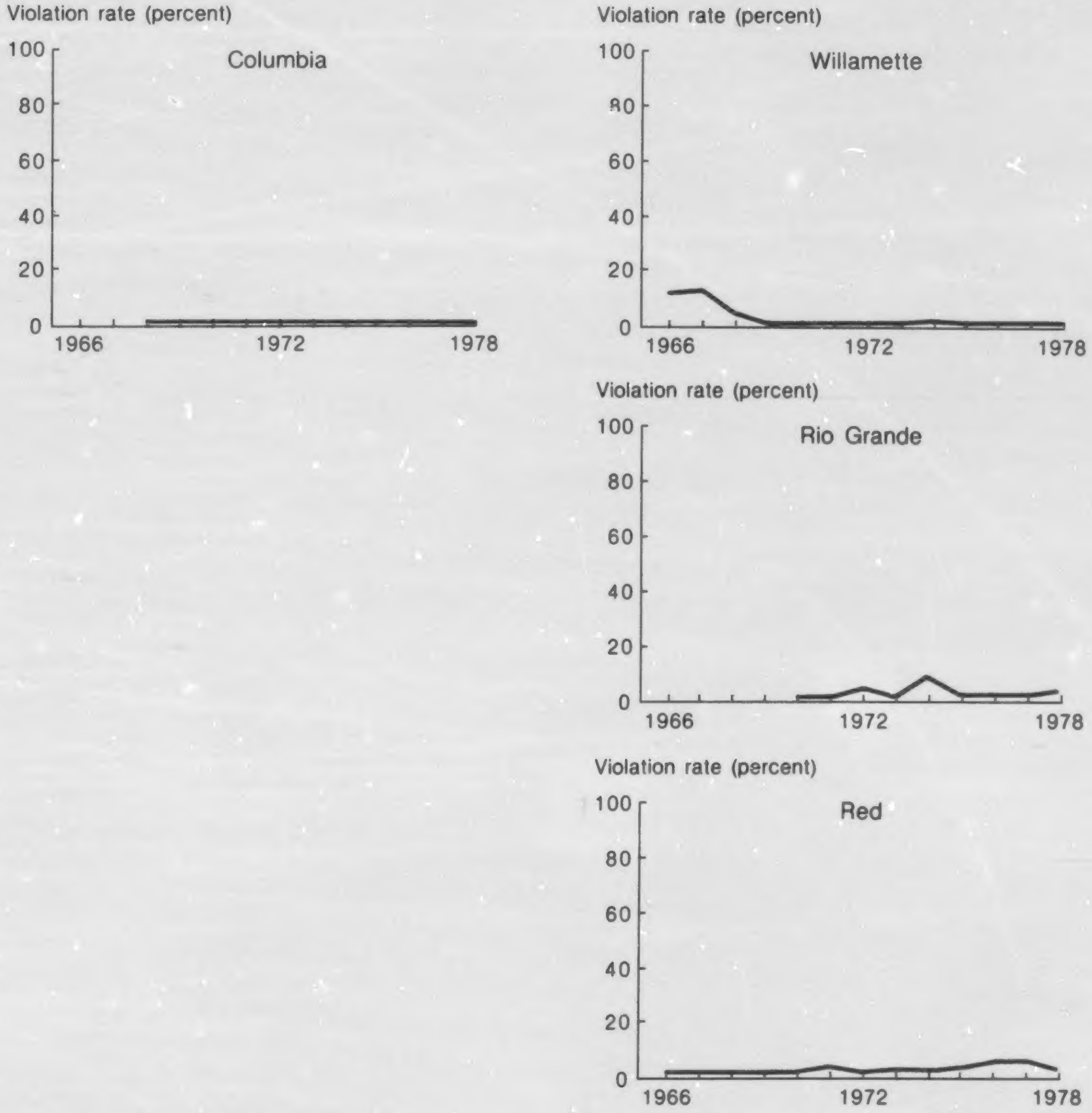

Violation rate (percent)
100
50-99
1-49
0
Data not available

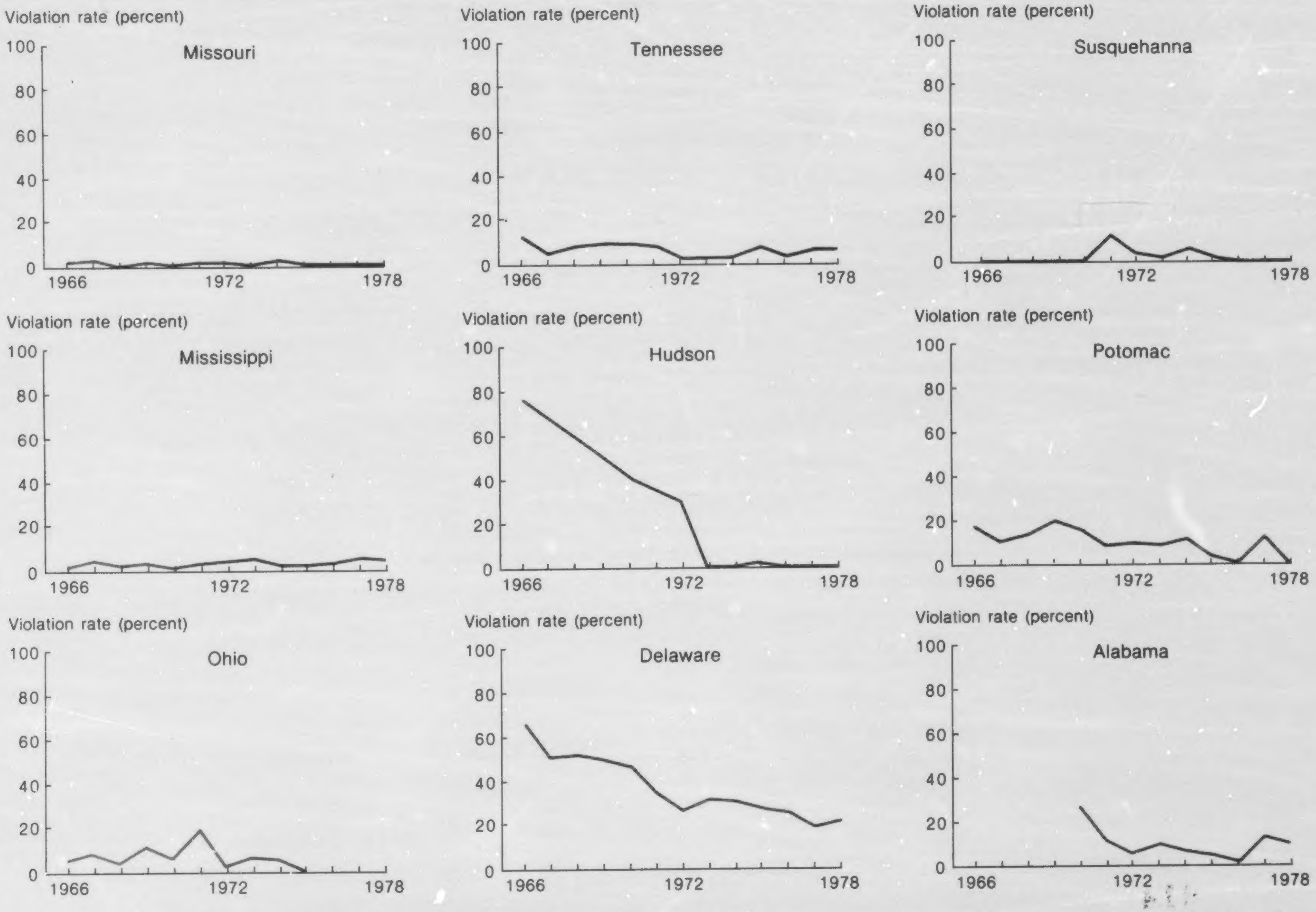
Of 326 (out of 350) accounting units reporting in 1978, 253—78%—reported no violation of the dissolved oxygen criterion. Only 10 reported violation rates more often than 20% of the time. However, two areas were consistently at very high levels from 1975 to 1978—the New River on the California-Mexico border, with violation rates of nearly 100%, and the Kissimmee River and canal system in southern Florida, with violation rates of 30% to 40%.

11-7

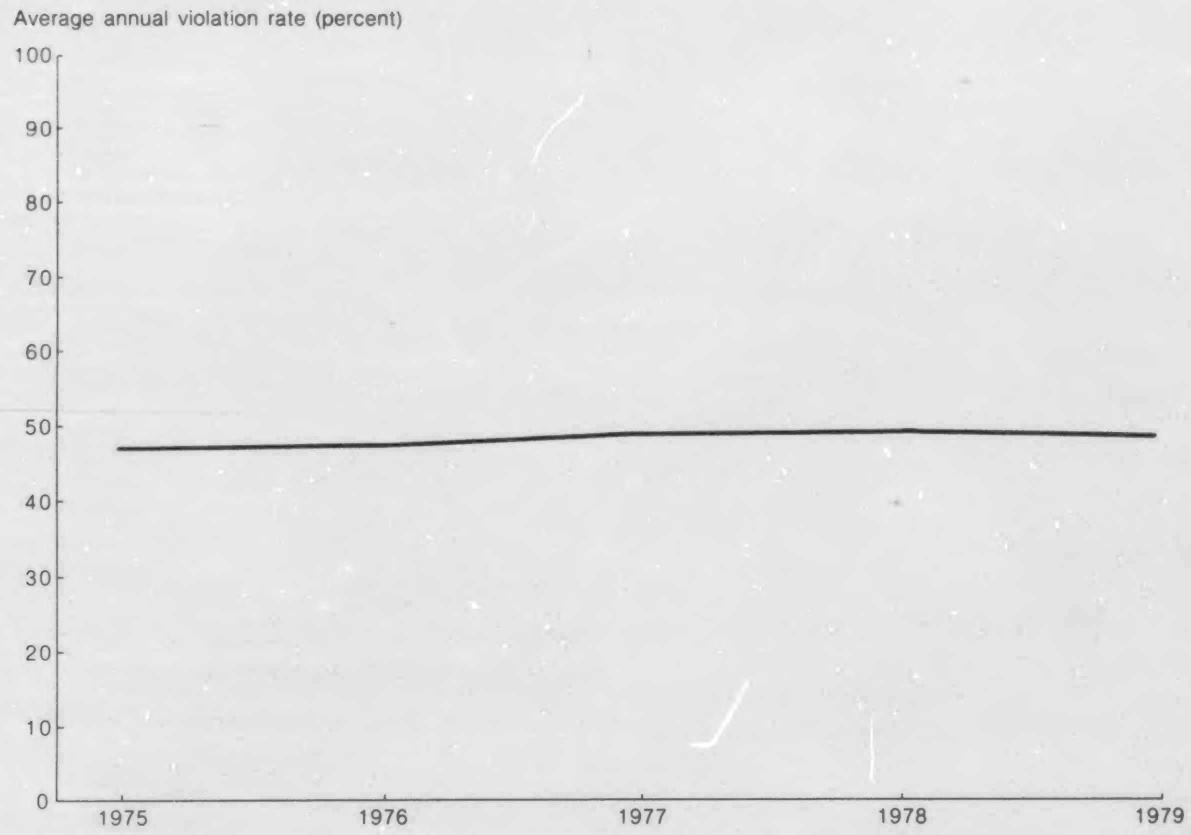
Dissolved oxygen in major rivers, 1966–1978

Violation of the dissolved oxygen standard is relatively rare in major rivers. The Hudson and Delaware have shown the most improvement of those studied.




Violation rate (percent)
Missouri
Tennessee
Susquehanna
Mississippi
Hudson
Potomac
Ohio
Delaware
Alabama
0
20
40
60
80
100
1966
1972
1978

11-8
Total phosphorus, average annual violation rates, 1975–1979



Levels of phosphorus, a nutrient essential for all life, can indicate a change in the character of a fresh water river or stream. Excessive phosphorus can stimulate growth of algae and other plants, and thereby accelerate eutrophication of waterways. Sources of phosphorus include municipal sewage, phosphate detergents, agricultural runoff (including fertilizers), and natural deposits in rocks.

The criterion for total phosphorus set to prevent the growth of nuisance plants is 0.1 milligrams per liter of water.

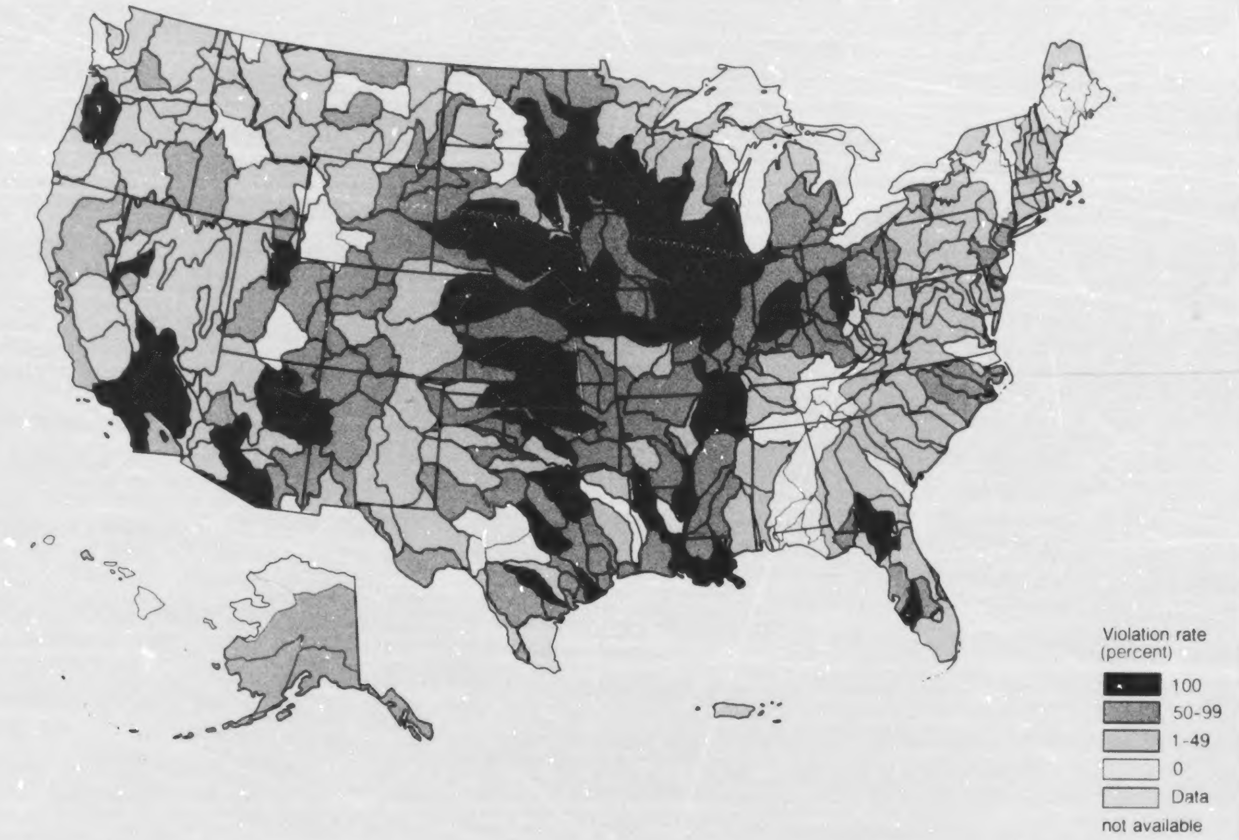
The average annual violation rate for total phosphorus in 1979 was 47%, roughly the same since 1975. This means that in 47% of all measurements taken, total phosphorus levels exceeded the nationally recommended level.

418

419

11-9

Total phosphorus in U.S. waters, 1978


Violation rate (percent)
■ 100
▩ 50-99
▨ 1-49
☐ 0
☐ Data not available

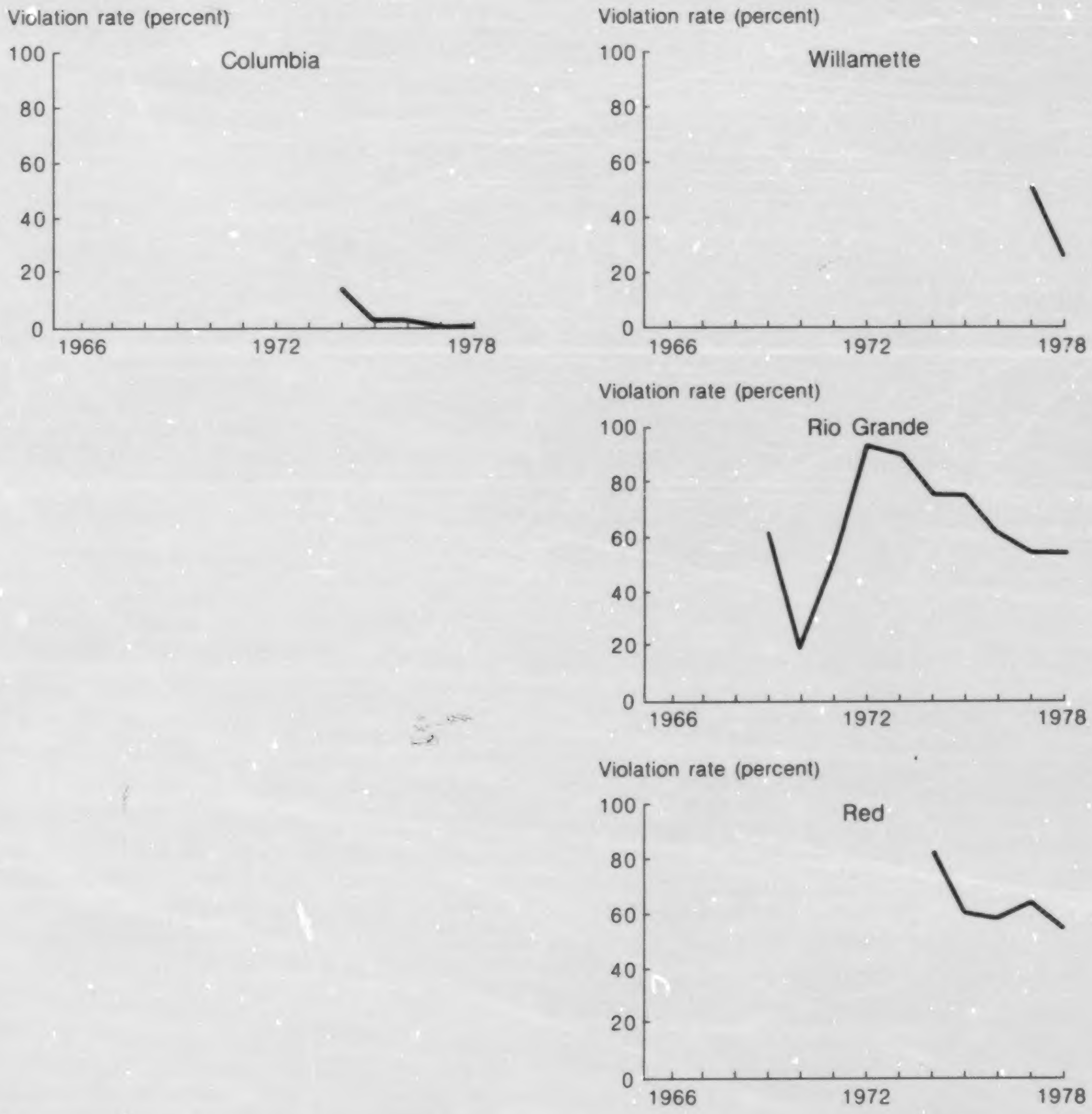
Phosphorus violation rates of 100% are common in the central States because of agricultural runoff, detergent use, erodible soils, and human waste. Highest violation rates are in the Mississippi River, its major tributaries, and the Missouri River.

420

421

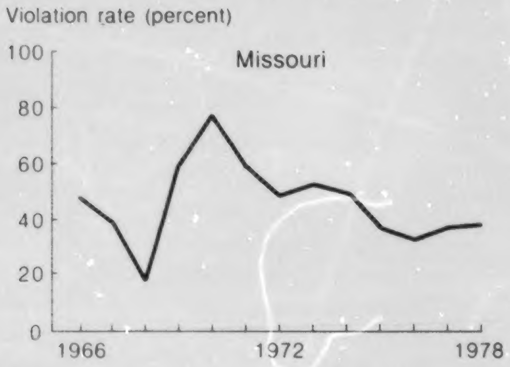
11-10
Total phosphorus in major rivers, 1966–1978

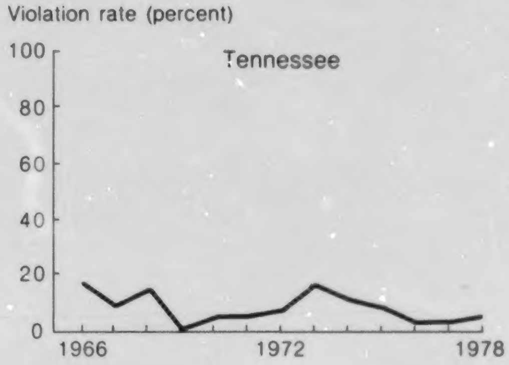
The number of phosphorus violations has declined substantially in 7 of 11 major rivers for which sufficient data were available. Two rivers showing no substantial improvement are the Mississippi and the Susquehanna. Violation rates for the Tennessee and the Columbia have not exceeded 20% in recent years.

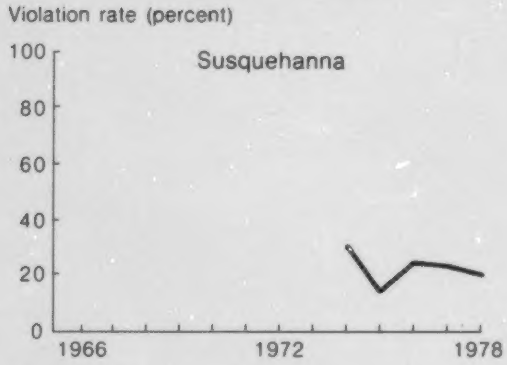


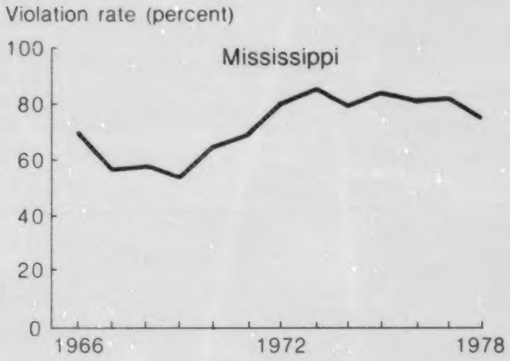
422

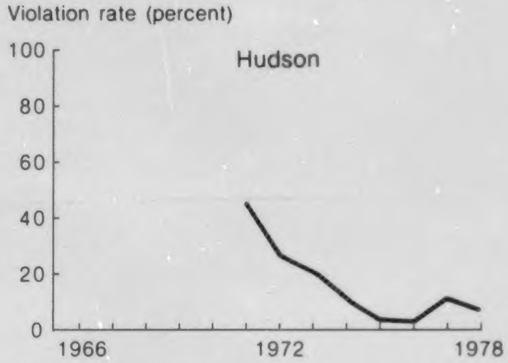
423

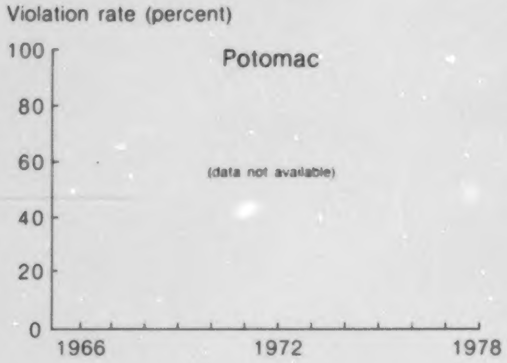

Violation rate (percent)
Missouri
100
80
60
40
20
0
1966
1972
1978

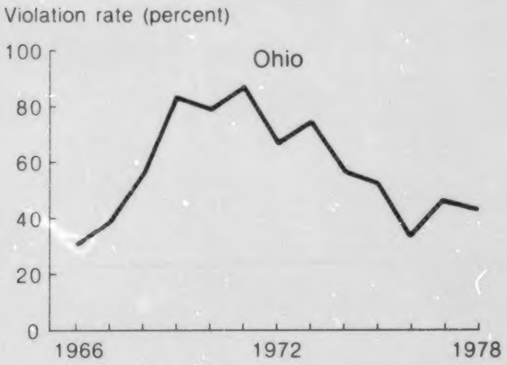

Violation rate (percent)
Tennessee
100
80
60
40
20
0
1966
1972
1978

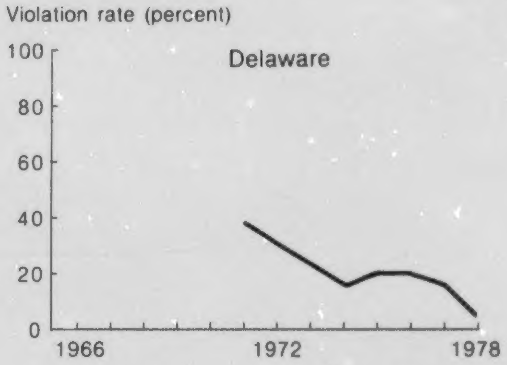

Violation rate (percent)
Susquehanna
100
80
60
40
20
0
1966
1972
1978

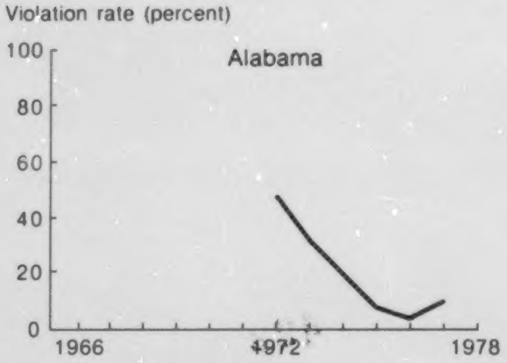

Violation rate (percent)
Mississippi
100
80
60
40
20
0
1966
1972
1978


Violation rate (percent)
Hudson
100
80
60
40
20
0
1966
1972
1978

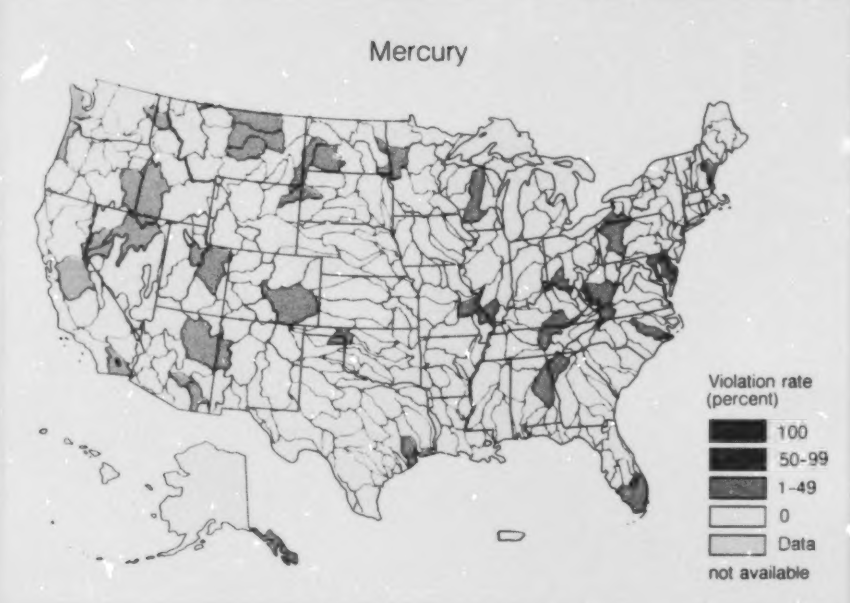

Violation rate (percent)
Potomac
(data not available)
100
80
60
40
20
0
1966
1972
1978

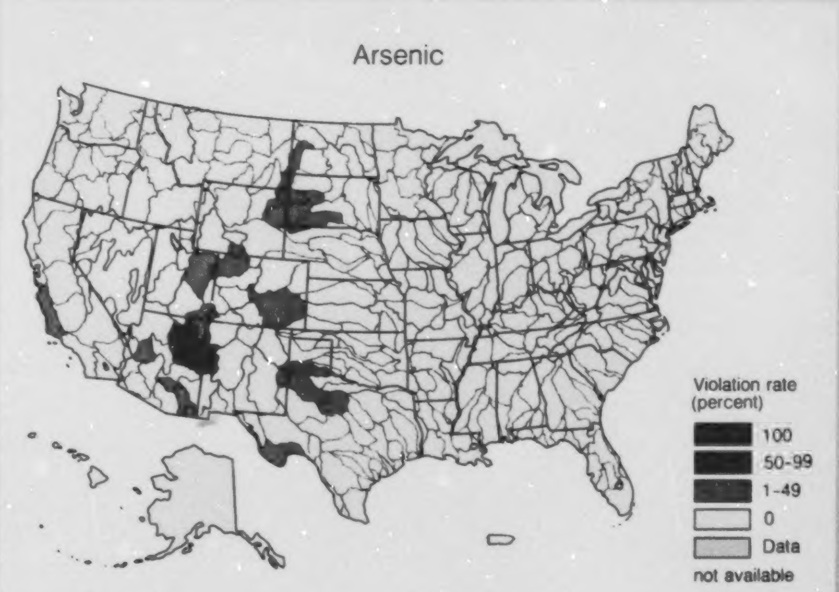

Violation rate (percent)
Ohio
100
80
60
40
20
0
1966
1972
1978


Violation rate (percent)
Delaware
100
80
60
40
20
0
1966
1972
1978


Violation rate (percent)
Alabama
100
80
60
40
20
0
1966
1972
1978

11-11
Heavy metals, 1975-1978


Mercury


Arsenic

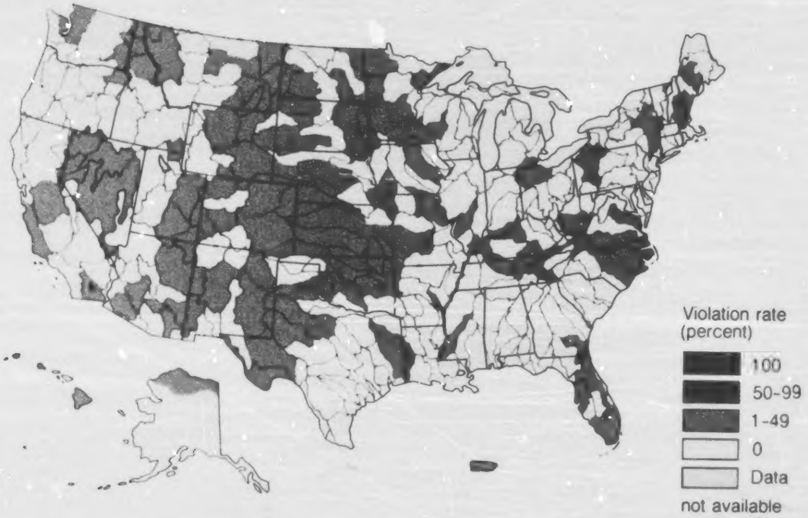
Almost all the States report water quality problems from toxic substances. Often only a small portion of the river or stream is affected. The most common problem reported is that of metals.

Heavy metals are concentrated in rivers as runoff leaches minerals from the soil. Mining, industrial discharges, combined sewer overflow, urban runoff, and solid waste disposal increase their concentrations.

Heavy metals are not completely removed by common wastewater treatment. As a result, they build up in water bodies, concentrate in the sediments, and are bioaccumulated in higher animals in the food chain. They contaminate the ground water. Short-term high concentrations or long-term low dosages can cause serious illness or death to aquatic and human life.

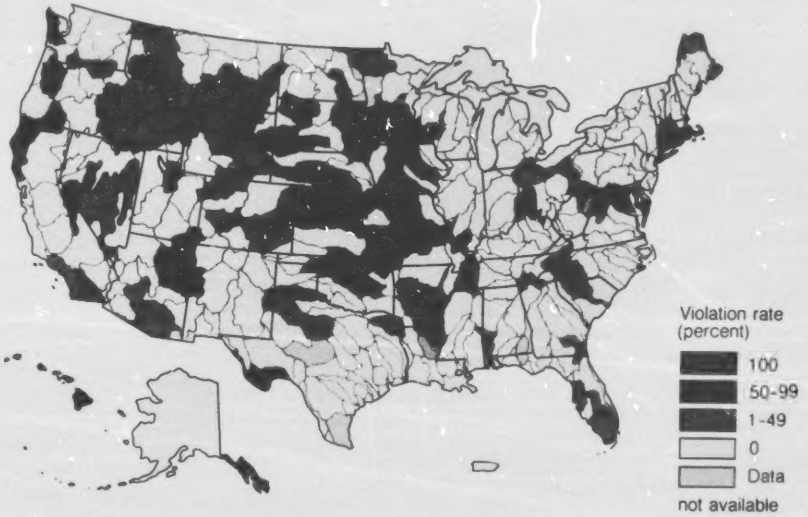
Mercury is widely distributed in the environment, with mining, agricultural, and power plant waste discharges adding to natural occurrences. There are few violations of recommended levels; only 40 (out of 350) accounting units reported violations between 1975 and 1978, most of them one-time violations.

Compounds of arsenic are also widely distributed in nature, with additions to waterways from industrial processes, herbicides, and other manmade sources. Most violations of the criterion were in the West.


Cadmium

Violation rate (percent)
100
50-99
1-49
0
Data not available

Cadmium is found in nature in association with zinc and lead. Although a third of the accounting units reported violations between 1975 and 1978, the violation rate did not exceed 36%. Some of the highest concentrations were in mining and smelting areas of the West.

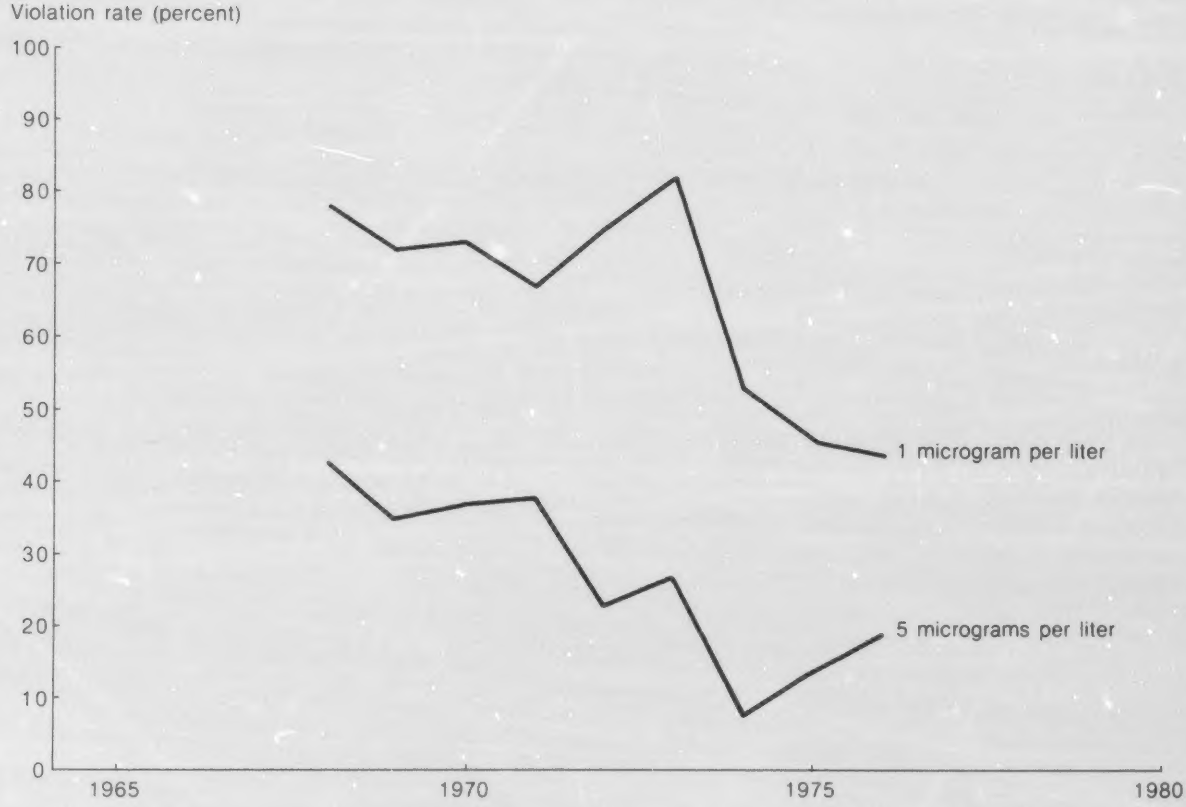

Lead

Violation rate (percent)
100
50-99
1-49
0
Data not available

Lead is added to the environment during mining, smelting, and processing the ore and through disposal of solid wastes. Vast quantities of lead are emitted by automobiles. The highest concentrations are principally in the Southwest, where lead occurs naturally.

11-12

Phenols in the upper Ohio River basin, 1968–1976



Phenols are synthetic organic compounds used in oil refineries and in the chemical and iron and steel industries. They generally indicate the presence of industrial water pollution.

The upper Ohio River, with its aggregation of heavy industry, is monitored for phenol pollution. Phenol concentrations here are improving because of industrial waste treatment and acid mine drainage control. Less acid water supports more microorganisms which can break down phenols.

Some areas of the river basin, such as along the Mahoning, have shown little or no improvement. Annual violation rates remained at nearly 100% there from 1968 to 1976.

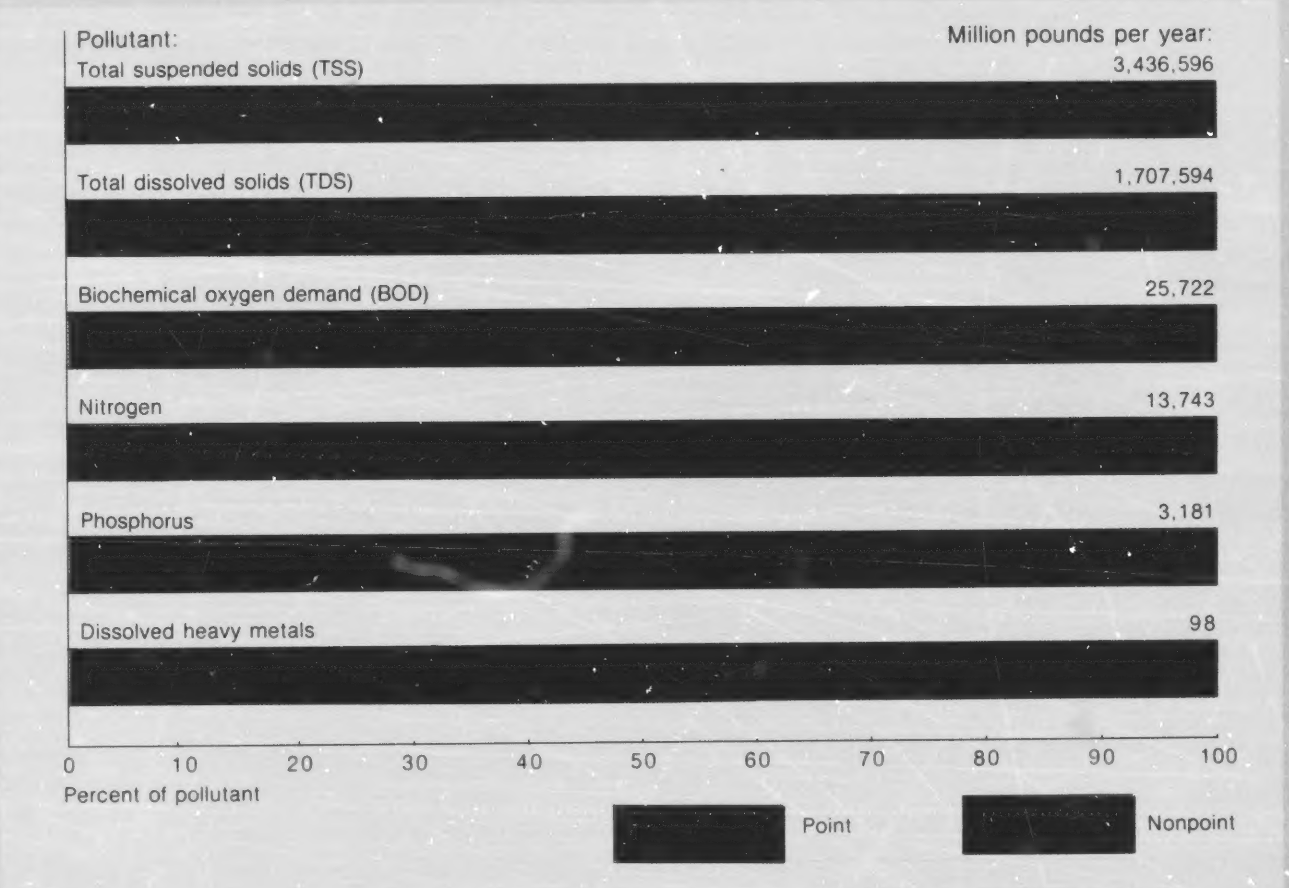
11-13

Discharges to water, by pollutant and by point and nonpoint sources, 1977

To decrease pollution levels, government and industry have concentrated on controlling the discharges that contain the pollutants. Discharges into rivers and streams, lakes, estuaries, reservoirs, oceans, and ground water come from specific point sources, primarily industrial and municipal discharge pipes and general nonpoint sources—namely, agricultural runoff, urban runoff, and solid waste disposal sites.

Pollutants in the discharges are most often total suspended solids, biochemical oxygen demand, nitrogen, phosphorus, and heavy metals.

Enormous volumes of material are discharged into U.S. waterways each year, most of it from nonpoint sources.



11-14

Point source discharges to water, by sector, 1977

Municipal sewage facilities are the principal point source pollutors to waterways. Other major dischargers are the organic chemical industry, agricultural feedlots, powerplants, and pulp and paper mills.

Total suspended solids

Sector	Million pounds per year
Municipal sewage plants	3,850.0
Powerplants	1,165.7
Pulp & paper mills	781.8
Feedlots	422.0
Iron & steel mills	254.3
Organic chemicals	144.0
Misc. food & beverages	91.9
Textiles	61.7
Mineral mining	52.7
Seafoods	50.0
Total, top 10 sectors	6,874.1
Total, all sectors	13,746.0
Top 10 sectors as percent of all sectors	50%

Total dissolved solids

Sector	Million pounds per year
Organic chemicals	36,540.4
Municipal sewage plants	30,255.2
Powerplants	18,418.1
Pulp & paper mills	16,825.8
Misc. chemicals	8,176.4
Misc. food & beverages	7,420.2
Oil & gas extraction	6,077.0
Petroleum refining	2,389.8
Coal mining	1,328.7
Iron & steel mills	1,324.0
Total, top 10 sectors	128,755.6
Total, all sectors	170,759.0
Top 10 sectors as percent of all sectors	75%

Biochemical oxygen demand

Sector	Million pounds per year
Municipal sewage plants	3,800.0
Pulp & paper mills	530.2
Organic chemicals	107.6
Feedlots	95.9
Seafoods	86.9
Misc. food & beverages	54.8
Cane sugar mills	50.4
Iron & steel mills	37.8
Misc. chemicals	35.2
Textiles	24.8
Total, top 10 sectors	4,823.6
Total, all sectors	6,944.0
Top 10 sectors as percent of all sectors	69%

Nitrogen

Sector	Million pounds per year
Municipal sewage plants	813.5
Pharmaceuticals	87.6
Organic chemicals	41.1
Feedlots	39.9
Meat packing	36.0
Petroleum refining	15.5
Misc. food & beverages	12.3
Seafoods	9.5
Pesticides	8.9
Leather tanning	7.1
Total, top 10 sectors	1,071.4
Total, all sectors	1,237.0
Top 10 sectors as percent of all sectors	87%

Phosphorus

Sector	Million pounds per year
Municipal sewage plants	73.9
Feedlots	21.8
Misc. food & beverages	4.7
Meat packing	3.4
Laundries	3.3
Fertilizers	2.6
Petroleum refining	1.5
Seafoods	1.4
Organic chemicals	1.4
Poultry	1.2
Total, top 10 sectors	115.2
Total, all sectors	191.0
Top 10 sectors as percent of all sectors	60%

Dissolved heavy metals

Sector	Million pounds per year
Powerplants	24.4
Municipal sewage plants	9.3
Iron & steel mills	7.6
Petroleum refining	6.0
Organic chemicals	3.6
Ore mining	2.5
Electroplating	0.5
Machinery	0.5
Oil & gas extraction	0.4
Foundries	0.1
Total, top 10 sectors	54.9
Total, all sectors	59.0
Top 10 sectors as percent of all sectors	93%

11-15

Population served by municipal wastewater systems, by level of treatment, 1960-1978

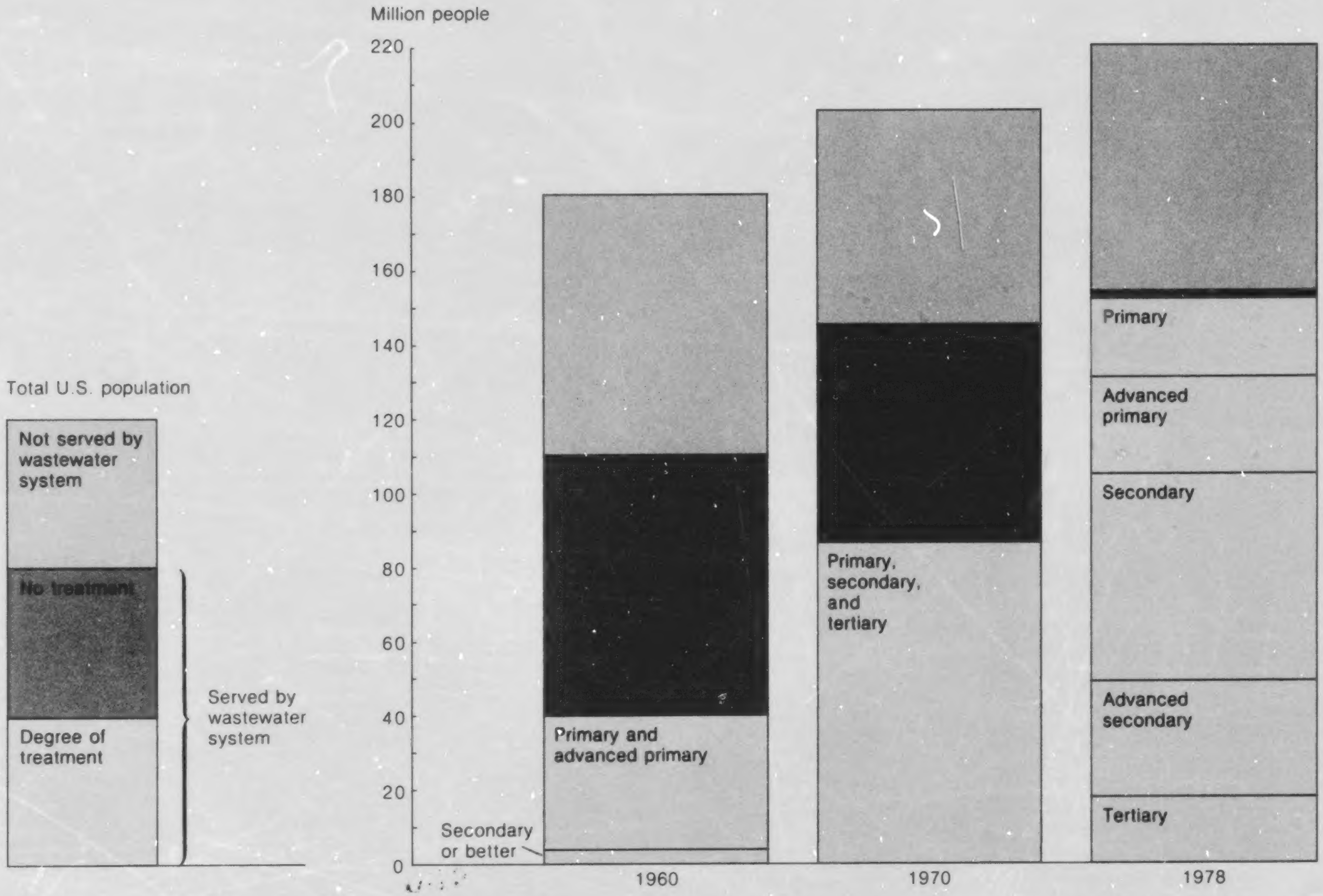
Seventy percent of the population has sewer service, and almost all—99%—of the sewered wastes receive treatment of some kind.

There are three main levels of municipal wastewater treatment—primary, secondary, and tertiary.

Primary treatment usually involves the physical separation of particulate matter from raw sewage by settling out the heavier solids and skimming off the lighter ones. This process removes between 20% and 35% of what is known as biochemical oxygen demand, one measure of oxidizable matter in water. Advanced primary treatment can involve the use of lagoon systems and other methods of treatment to further reduce biochemical oxygen demand and the amount of suspended solids.

In secondary treatment, biological degradation is usually employed to reduce biochemical oxygen demand and remove total suspended solids by 85% or more.

Tertiary treatment commonly uses chemical and physical means to remove nutrients (phosphorus and nitrogen) and other contaminants such as toxic substances that remain after secondary treatment.


Total U.S. population
Not served by wastewater system
No treatment
Degree of treatment
Served by wastewater system
Million people
220
200
180
160
140
120
100
80
60
40
20
0
Primary and advanced primary
Secondary or better
Primary, secondary, and tertiary
Primary
Advanced primary
Secondary
Advanced secondary
Tertiary
1960
1970
1978

11-2
Fecal coliform bacteria, average annual violation rates, 1975–1979

Council on Environmental Quality, Washington, D.C. UPGRADE analysis of the U.S. Geological Survey National Stream Quality Accounting Network (NASQAN) data. NASQAN data are published for each State by the U.S. Geological Survey in *Water resources data for [State], 197[ ] water year.*

The 1975 data for all States and all NASQAN stations are printed in *Quality of rivers in the United States, 1975 water year—based on the National Stream Quality Accounting Network (NASQAN),* U.S. Geological Survey (Reston, Va., 1977), open file rep. 78-200. The 1976 data are expected to be published in 1981.

Fecal coliform (FC), dissolved oxygen (DO), phosphorus, and metals data are from approximately 470 NASQAN stations in 350 hydrologically based accounting units. NASQAN is considered uniform because the same pollutants are measured at all stations under standardized conditions of collection, frequency, and analytical methods. FC, DO, and phosphorus are measured monthly and metals are measured quarterly, weather and other conditions permitting.

Years refer to water years. A water year begins in October and ends in September; for example, 1975–1979, begins in October 1974 and ends in September 1979.

Although there are no Federal standards for water quality, Federal agencies have recommended acceptable levels for a number of pollutants—criteria which regional, State, and local governments are encouraged to adopt.

The composite violation rate represents the proportion of all measurements of a specific water quality variable which exceeds the violation level for that variable. Although violation levels are based on published water quality criteria, the word "violation" is used for simplicity and does not necessarily imply a legal violation.

The pollutants, criteria (violation levels), and water use relative to the criteria are: *Fecal coliform,* above 200 cells/100 ml, swimming; *dissolved oxygen,* below 5.0 mg/l, desirable fish populations; *total phosphorus,* below 0.1 mg/l, prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments; *total mercury,* above 2.0 μg/l for domestic water supply, above 0.05 μg/l for fresh water fish and wildlife; *total arsenic,* above 100 μg/l for crop irrigation, above 50 μg/l for domestic water; *total cadmium,* above 10 μg/l for domestic water; *total lead,* above 50.0 μg/l for domestic water. (These levels are listed in *Quality criteria for water,* U.S. Environmental Protection Agency (Washington: USGPO, 1976).)

"The composite violation rate has several important advantages as an indicator. First, it relates the water quality data to known reference levels, many of which are associated with potential impacts such as beach closings or harm to aquatic life. Second, the composite indicator statistically reduces the bias caused by any high values erroneously recorded, a problem with most large data bases, in contrast to certain other measures such as mean values. Third, the composite violation rate can be applied flexibly. It can be used for a single monitoring station, all the stations on a river or river reach, or even the entire nation.

"As with most other indicators and statistical measures, some of the year-to-year variation in composite violation rates may not represent significant changes in water quality. Instead, the variation may be due to changes in streamflow, temperature, measurement schedules, and other factors. A genuinely significant improvement or worsening in a particular water quality variable usually becomes apparent only after several years of consistently different values have been measured in a river." (*Environmental quality—1976,* Council on Environmental Quality (Washington: USGPO, 1976), p. 271.)

11-3
Fecal coliform bacteria in U.S. waters, 1978

See 11-2.

Years refer to water years. See 11-2.

11-4
Fecal coliform bacteria in major rivers, 1966–1978

Council on Environmental Quality, UPGRADE analysis of the U.S. Environmental Protection Agency's Storage and Retrieval (STORET) data.

These 13 rivers were selected from 22 waterways analyzed by the U.S. Environmental Protection Agency. The 22 rivers and bays were the 10 longest rivers, the 10 with the highest flow (cubic feet per second), and were in or near the 10 largest urban areas.

The 13 rivers were those with the most complete data available. (Other major rivers, such as the Colorado, were excluded because of data limitations.) Most of the stations on the 13 are operated by the U.S. Geological Survey, but data were also included from several State and other Federal agencies.

Because all stations did not operate continuously and some took more measurements than others, the data may be biased toward conditions where FC, DO, or phosphorus were measured more frequently.

Data shown here have at least 20 observations per river per year from all stations combined. For any year shown with no data, either that parameter was not measured, was measured but not reported to STORET, or was measured infrequently (less than 20 observations per year).

Data for 1978 are preliminary.

11-5
Dissolved oxygen, average annual violation rates, 1975–1979

See 11-2.

Years refer to water years. See 11-2.

11-6
Dissolved oxygen in U.S. waters, 1978

See 11-2.

11-7
Dissolved oxygen in major rivers, 1966–1978

See 11-4.

Values higher than 20 milligrams per liter were excluded because of possible errors or poor samples.

Data for 1978 are preliminary.

11-8
Total phosphorus, average annual violation rates, 1975–1979

See 11-2.

Measurements of total phosphorus include dissolved phosphorus and phosphorus associated with suspended solids.

Years refer to water years.

11-9
Total phosphorus in U.S. waters, 1978

See 11-2.

11-10
Total phosphorus in major rivers, 1966–1978

See 11-4.

Values higher than 2.5 micrograms per liter were excluded because of possible errors or poor samples.

Data for 1978 are preliminary.

11-11
Heavy metals, 1975–1978

See 11-2.

Violations of mercury, cadmium, and lead levels are based on criteria for domestic water supply. Violations of arsenic levels are based on criteria for crop irrigation. See 11-2 for criteria levels.

Data are based on measurements of total heavy metals, which include dissolved metals and metals associated with suspended solids.

The 1975–1978 data for mercury, arsenic, and cadmium refer to the percentage of all observations in 1975–1978 which were in violation of the criteria. In other words, the statistic mapped for each accounting unit is the ratio of all observations in violation divided by the total number of observations from all stations in that accounting unit for the 4-year period.

Data for lead are for 1978 only. Lead data for 1975–1977 are not comparable to 1978 data because of changes in measurement techniques.

Years refer to water years.

11-12
Phenols in the upper Ohio River basin 1968–1976

Environmental quality—1977, Council on Environmental Quality (Washington: USGPO, 1977), UPGRADE analysis of the U.S. Environmental Protection Agency's STORET data, pp. 246, 248.

The upper Ohio River is the 300 miles between Pittsburgh and approximately Huntington, W. Va.

For 1968–1975, the composite violation rate was calculated from measurements at 14 State, local, and Federal sites. For 1976, 10 Ohio River Sanitation Commission stations were studied.

The phenol criterion is 1 microgram per liter in Ohio and 5 micrograms per liter in Pennsylvania and West Virginia.

11-13
Discharges to water, by pollutant and by point and nonpoint source, 1977

"Estimates of national water pollutant discharges by polluting sector: 1977," L. P. Gianessi and H. M. Peskin, unpublished tables assembled under National Science Foundation grant SOC 77 15045, as part of the Environmental Policy Evaluation Program of Resources for the Future.

Estimates made in April 1980.

11-14
Point source discharges to water, by sector, 1977

See 11-13.

11-15
Population served by municipal wastewater systems, by level of treatment, 1960–1978

1960 and 1970: "Market for water and wastewater treatment equipment," K. L. Kollar, *J. Water Pollution Control Fed.* 51:682 (1979).

1978: *1978 needs survey, conveyance and treatment of municipal wastewater, summaries of technical data,* U.S. Environmental Protection Agency (Washington: USGPO, 1979), FRD-2, tables 7, 8, 16, 26, 30, 44, pp. 19, 21, 37, 57, 65, 125.

Data for 1960 and 1970 are not strictly comparable to 1978 data because of different methods of data collection.

In 1978, there were more than 20,000 wastewater facilities in operation throughout the country removing some 75% (11 million pounds/day) of BOD_5 and 78% (also 11 million pounds/day) of suspended solids. BOD_5 is the amount of oxygen consumed metabolically by test microorganisms in a sample in 5 days.

1978 primary treatment also includes 2 million people who are served by wastewater treatment systems that have no discharges to surface waters.

1960–1970: Data aggregated by State from the 1960 and 1970 censuses of population.

An alternative to conventional wastewater treatment is land treatment, wherein wastewater is sprayed onto field crops. The water percolates through the soil to surface and ground waters. Land treatment produces effluent similar to or better than that of advanced secondary treatment systems and usually costs less. In addition, two nutrients in wastewater, nitrogen and phosphorus, promote agricultural growth.

Lakes

When large lakes are polluted, the cause is often industrial and municipal discharges dumped directly into tributaries. Pollution of small lakes and reservoirs is largely a function of local land use practices—the disposal of wastes, soil erosion, and runoff of fertilizers and pesticides from farmland and gardens. A major problem for many small lakes is silting.

Lakes are subject to two special problems. One is toxic substances, which are brought into lakes, become widely distributed, and can accumulate in the tissue of fish and other aquatic life. Wildlife which live on lake fish and plants may be threatened and are then of limited use as a food for humans.

A second problem is the acceleration of eutrophication—the natural aging of water bodies.

11-16
Eutrophication of U.S. lakes, 1975

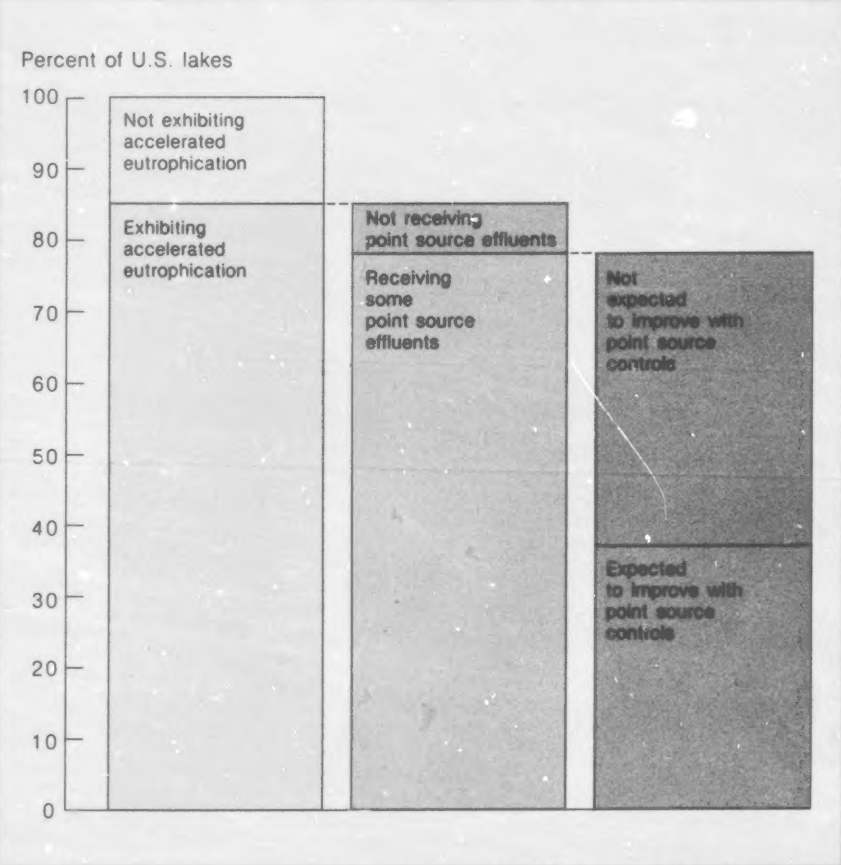
Eutrophication may well be the most widespread problem of lakes. In the process of eutrophication, nutrients and sediments increase, changing clear water to a cloudy lake, a swamp, and, eventually, to land. When it occurs naturally, the process takes thousands to millions of years, but human activity accelerates it, producing the same effect in a few decades.

Just over 85% of U.S. lakes may be eutrophying at an accelerated rate.

Of the lakes exhibiting accelerated eutrophication, nearly all receive waste discharges from industry and municipalities.

Even if these point sources were wholly controlled, less than half the affected lakes would improve because major contributors to eutrophication are nonpoint sources—agriculture, mining, forestry, and others.

Many lakes are undergoing accelerated eutrophication, while others are becoming overly acidic, causing a decline in biological activity. Acidic areas may result from acid mine drainage or from other discharges. Acidity also results from acid precipitation, a condition created by emissions from smelters, power plants, and other air polluting sources. Since 1955, acid precipitation in the East has increased substantially. Acid conditions decrease fresh water fish production and agricultural and forest yields.

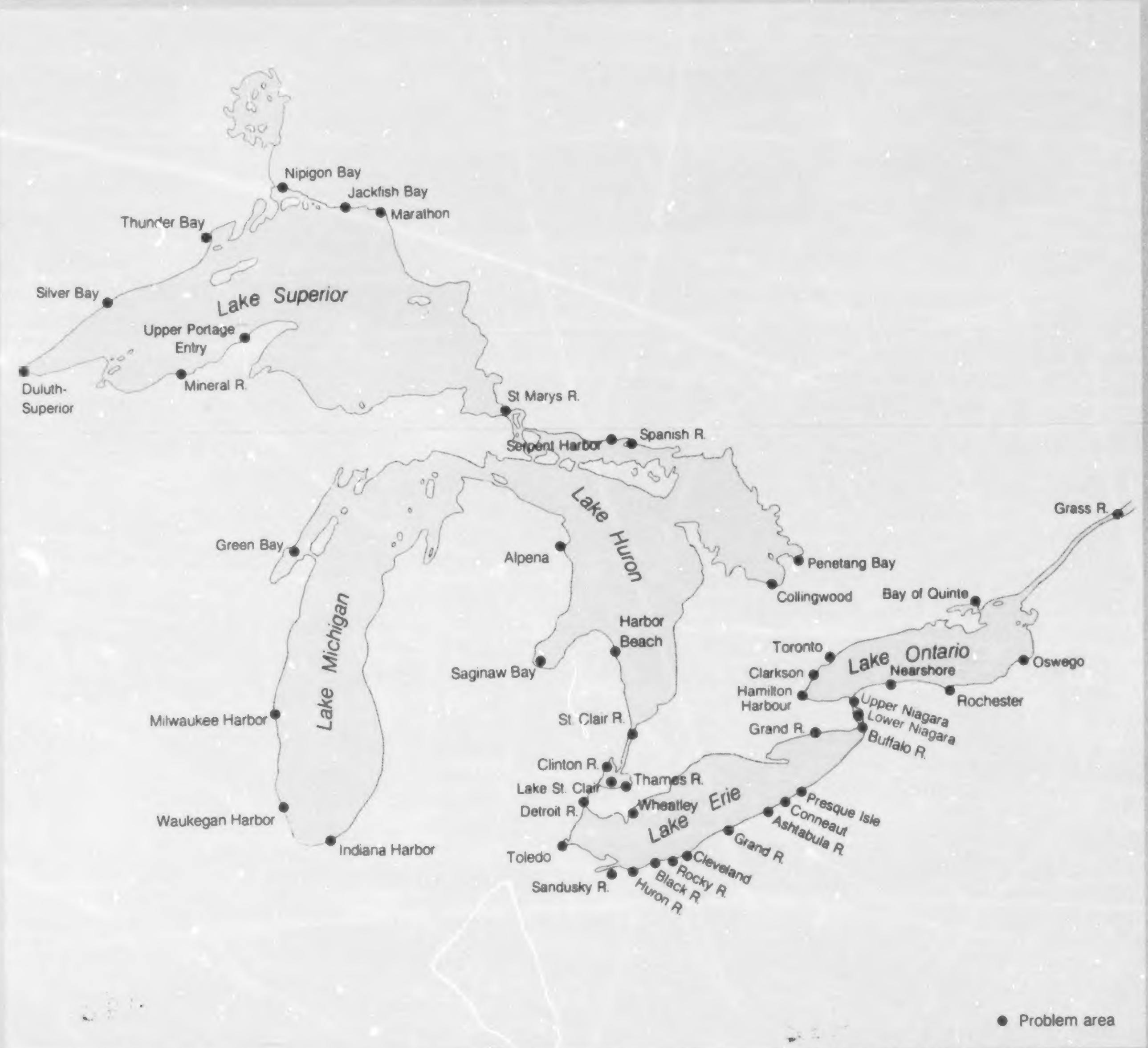


11-17
Water quality problem areas of the Great Lakes, 1978

The Great Lakes are the largest and most industrialized lakes in the United States. Their adjacent counties are the home of 37 million people, more than 15% of the total U.S. and Canadian populations. In 1978, the Great Lakes Water Quality Board designated 48 major problem areas on the U.S. and Canadian coasts. Problems included high levels of biochemical oxygen demand and high concentrations of phosphorus, total suspended solids, fecal coliform bacteria, and mercury, lead, copper, phenols, and PCBs.

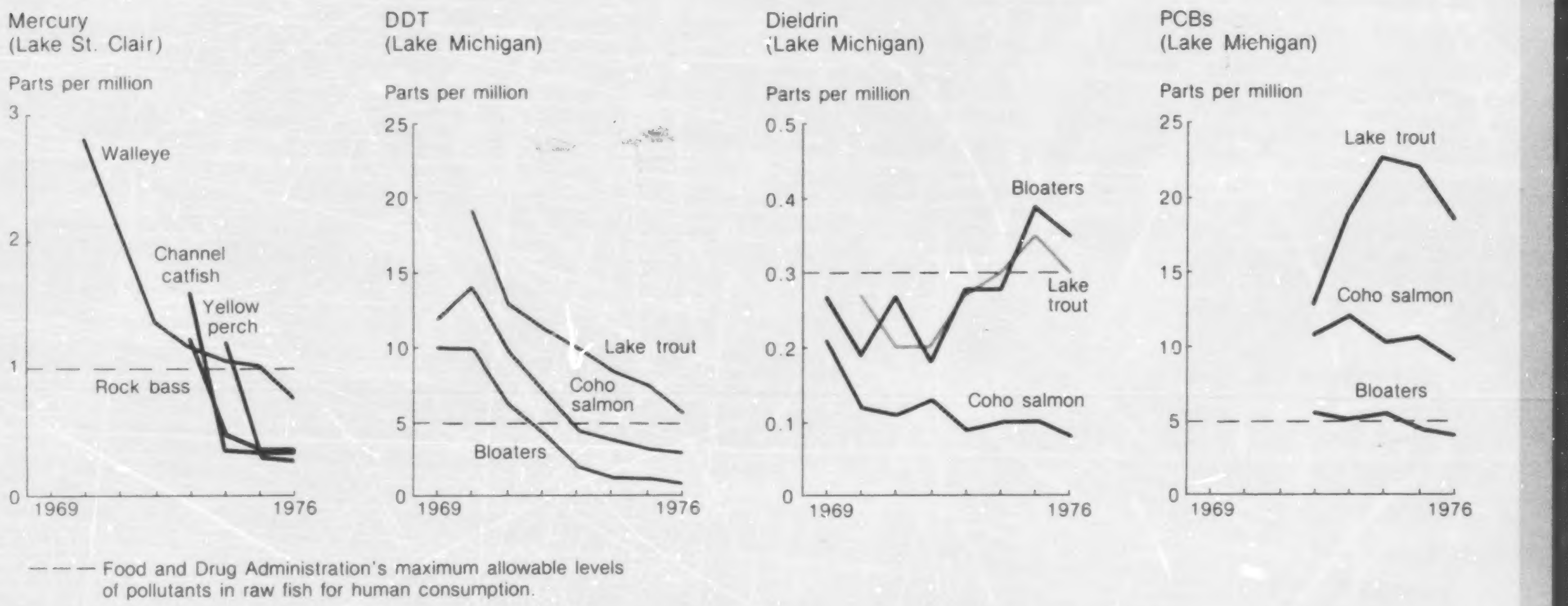
For Lakes Superior, Michigan, and Huron, degraded conditions are most often associated with industrial and metropolitan centers. The open water meets water quality criteria for fishing and swimming.

Lakes Erie and Ontario have many more problem areas than the other three lakes. For years, untreated industrial and municipal wastes were dumped directly into the lakes and their tributaries. Lake Erie has improved since 1972, when industrial pollutants from the Detroit River and other sources were reduced, but phosphates and nitrates continue to be introduced from point and nonpoint sources. The Great Lakes Water Quality Board has identified 17 problem areas in Lake Erie, including Cleveland, Toledo, and the Detroit River—Lake Erie's largest tributary.


Nipigon Bay
Jackfish Bay
Marathon
Thunder Bay
Silver Bay
Lake Superior
Upper Portage Entry
Duluth-Superior
Mineral R.
St Marys R.
Serpent Harbor
Spanish R.
Lake Huron
Grass R.
Green Bay
Alpena
Penetang Bay
Collingwood
Bay of Quinte
Lake Michigan
Harbor Beach
Saginaw Bay
Toronto
Lake Ontario
Oswego
Clarkson
Nearshore
Hamilton Harbour
Rochester
Upper Niagara
Lower Niagara
Milwaukee Harbor
St. Clair R.
Grand R.
Buffalo R.
Clinton R.
Thames R.
Lake St. Clair
Detroit R.
Wheatley
Lake Erie
Presque Isle
Conneaut
Ashtabula R.
Waukegan Harbor
Indiana Harbor
Toledo
Grand R.
Cleveland
Rocky R.
Black R.
Huron R.
Sandusky R.
● Problem area

11-18

Toxic residues in Great Lakes fish, 1969-1976



For the Great Lakes as a whole, toxic substances may be the most serious water quality problem. One indication of the presence of toxic substances is the residues in fish. The levels of some toxic substances are declining or are expected to decline but, in some species, levels make fish unacceptable for human consumption.

Mercury is declining in the lake in which it was most prevalent, Lake St. Clair, located between Lake Huron and Lake Erie.

DDT levels have declined in three species of fish in Lake Michigan.

Since it was banned for most purposes in 1974, levels of the pesticide dieldrin have not changed significantly, perhaps because of continued use of existing stock. It enters the lake primarily from agricultural runoff.

Residues of PCBs, a class of persistent industrial chemicals, are still above the Federal guidelines in some fish species.

Isolated sections of the Great Lakes have high concentrations of toxic substances. Because many toxic substances are not well monitored, overall water quality cannot be evaluated.

11-16
Eutrophication of U.S. lakes, 1975

U.S. Environmental Protection Agency, National Eutrophication Survey, unpublished data.

Data include 175 of the 775 lakes studied. The 775 lakes represent 6% of the 13,600 inland lakes and reservoirs which qualify as large water bodies.

The survey may be biased toward large water bodies (more than 100 acres) impacted by municipal wastewater discharges. In the East, selected lakes were impacted by one or more municipal sewage treatment plants.

11-17
Water quality problem areas of the Great Lakes, 1978

Great Lakes water quality: Seventh annual report to the International Joint Commission, Great Lakes Water Quality Board (Windsor, Ontario: International Joint Commission, 1979), fig. 2.6, p. 20.

11-18
Toxic residues in Great Lakes fish, 1969-1976

U.S. Fish and Wildlife Service, Great Lakes Fish Laboratory, Ann Arbor, Mich., unpublished data.

The Food and Drug Administration's levels are not strictly applicable to these data because the guidelines pertain only to edible portions of the fish and Fish and Wildlife Service analyzes the whole fish. Concentrations in edible portions are slightly lower than in whole fish.

The PCB level is under review and may be changed from 5 parts per million to 2.

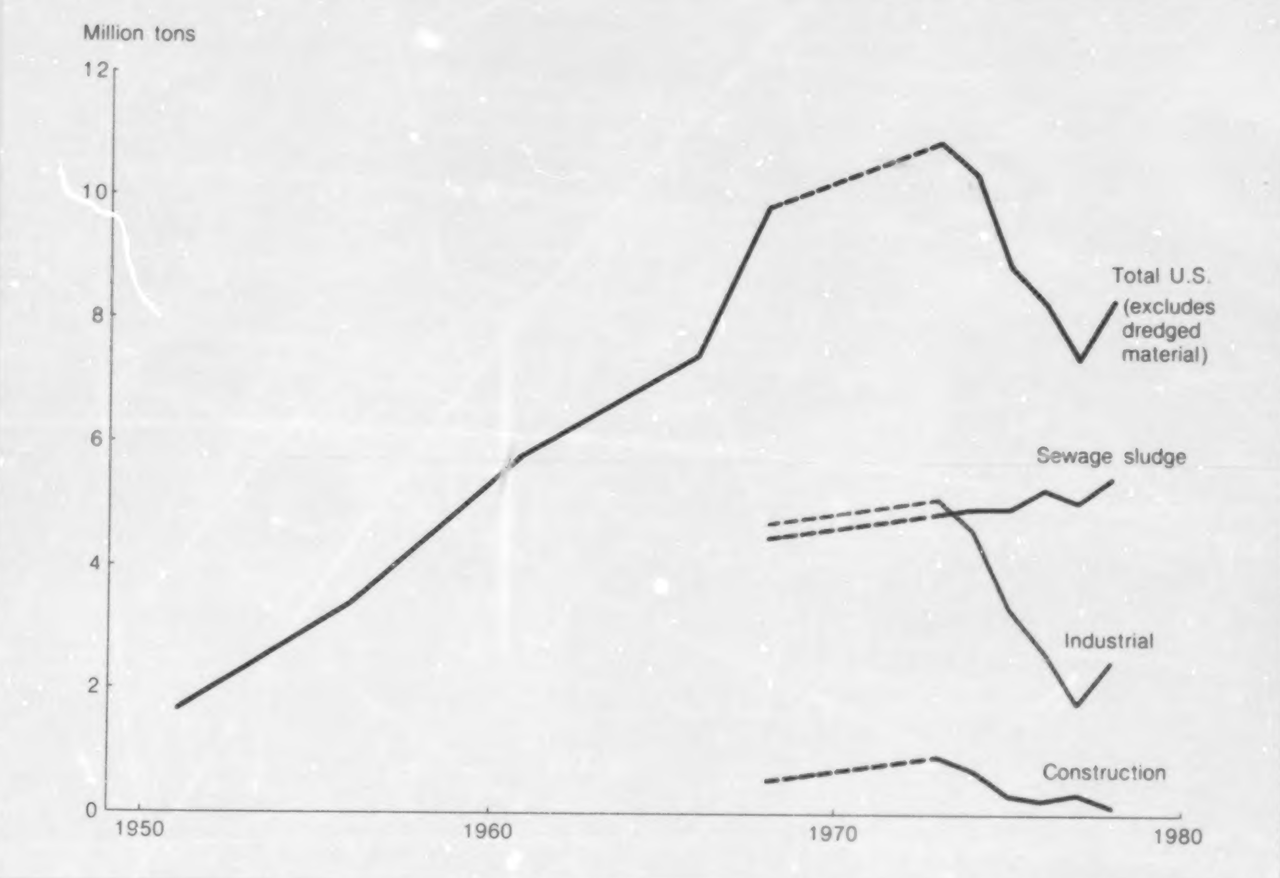
448

Oceans

The bays, estuaries, and seas receive waters from rivers and streams along with materials that are deliberately dumped. Fortunately, the sea is able to dilute and neutralize many types of wastes. Coastal waters cannot do as well. There—where many tiny organisms, shellfish, small fish, marine mammals, and waterfowl live and breed—pollutants can build up to harmful levels.

As the quality of water in the Nation's rivers improves, so will that of bays and estuaries. For the oceans, most protection efforts are aimed at reducing the amount and type of material dumped directly into them whether by accident or on purpose.

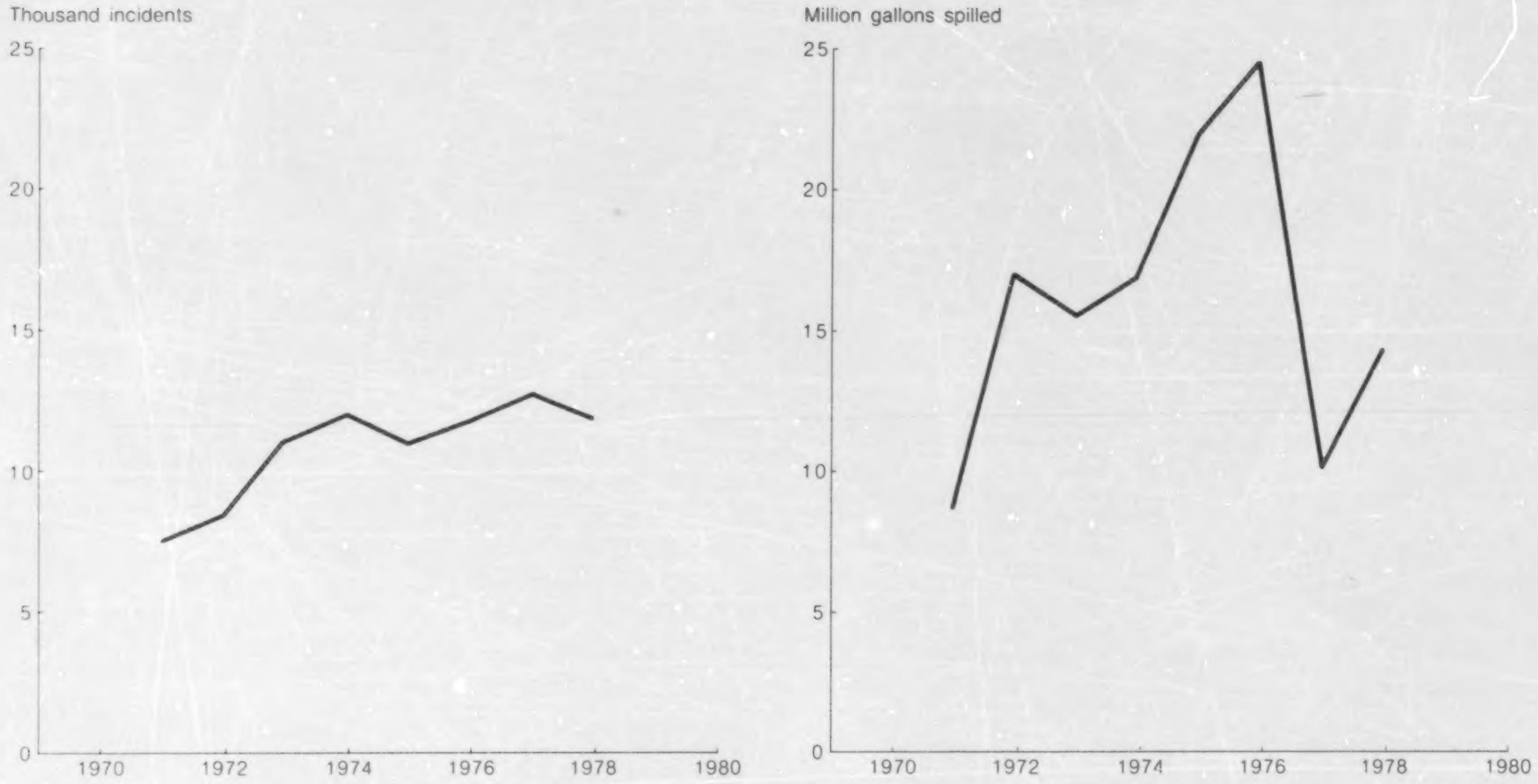
11-19
Ocean dumping of U.S. wastes by barge, 1951–1978



Ocean dumping is currently used to dispose of industrial wastes, sewage sludge, garbage, construction debris, derelict vessels, and dredged material. (The latter accounts for about 90% of the total amount dumped in the ocean.) Wastes are barged to specific sites or sent through outfall pipes. The dumped wastes severely affect marine life from toxicity, oxygen depletion, accelerated fertilization of plant life, and physical changes in the habitat. By law, all sludge and harmful industrial waste dumping in the oceans from barges must cease by 1981.

Since 1973, when a requirement for permits came into force, the amount of wastes dumped in U.S. coastal waters has decreased substantially. Most of the change has resulted from the decreased dumping of industrial wastes.

11-20
Oil spills in U.S. waters, 1971-1978

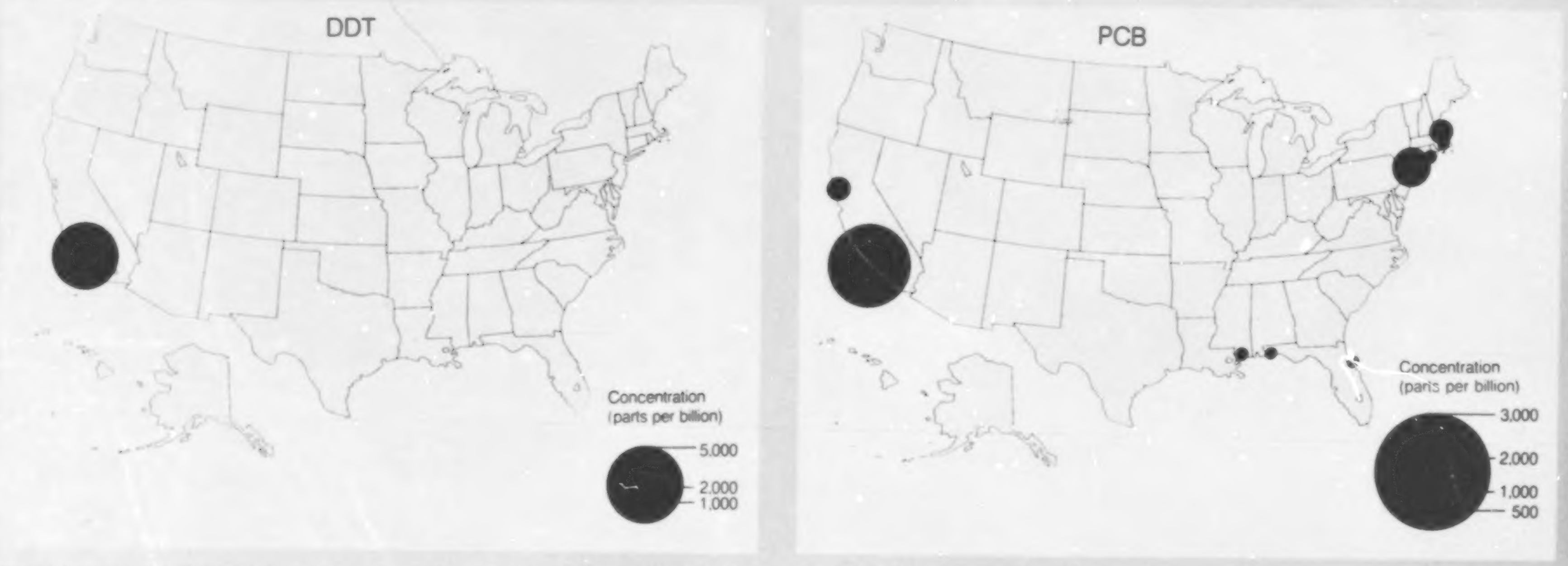


Oil spills continue to increase in number, but the size of the spills varies widely. A few incidents account for the majority of oil spilled in a given year. Between 1975 and 1977, an average of 17 spills accounted for 65% of the total amount spilled each year.

451

452

11-21
Toxic residues in coastal mussels and oysters, 1976

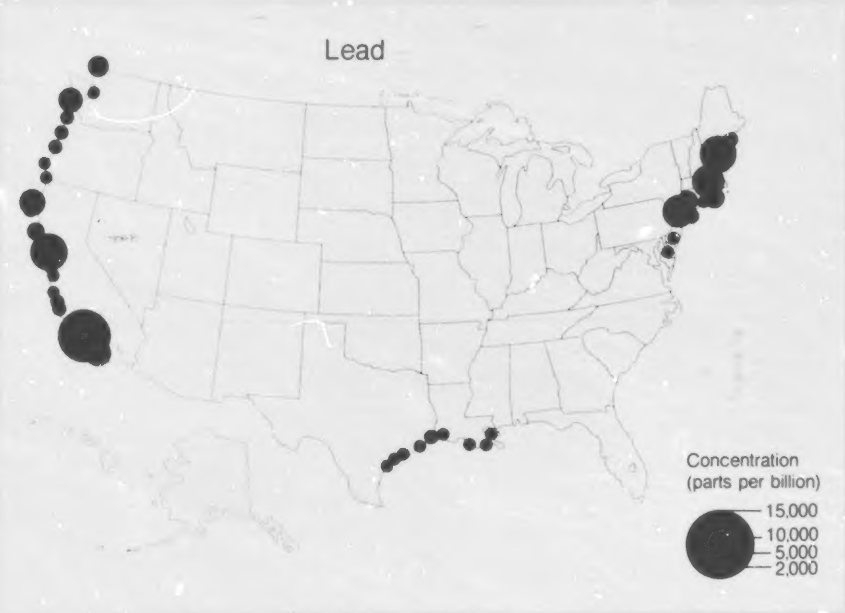

DDT
Concentration (parts per billion)
5,000
2,000
1,000
PCB
Concentration (parts per billion)
3,000
2,000
1,000
500

Ocean dumping and oil spills are only two of the more obvious sources of ocean pollution. Most ocean pollutants come from rivers and streams and direct runoff from the land. They are even more difficult to measure.

The presence of a few key toxic substances is being monitored in mussels and oysters, common along the ocean coasts. At 106 locations, samples are taken for the measurement of DDT, PCBs, and lead.

DDT concentrations are extremely high at only one site—San Pedro Harbor, California, a reminder of an environmental problem that was once widespread.

PCBs are found in areas of industrial activity and high population density. Hot spots—areas of high concentrations—are found on both east and west coasts. Levels of PCBs above 500 parts per billion, for example, reduce the growth potential of mussels.



Levels of lead, like PCBs, are most highly concentrated in industrial and densely populated areas.

Preliminary data for 1977 and 1978 show no marked changes in levels of DDT, PCBs, and lead along these coastlines. But a marked reduction from 1971 levels of DDT and PCBs is apparent along the California coast.

Sources and technical notes

11-19
Ocean dumping of U.S. wastes by barge, 1951–1978

1951–1968: *Ocean dumping, a national policy*, Council on Environmental Quality (Washington: USGPO, 1970), pp. 3, 8.
1973–1978: *Annual report to Congress, Jan.–Dec. 1978, on administration of the Marine Protection, Research, and Sanctuaries Act of 1972, as amended (P.L. 92-532) and implementing the International Ocean Dumping Convention*, U.S. Environmental Protection Agency (Washington: USGPO, 1979), pp. 16, 16A.

Data for 1951–1968 may not be strictly comparable to data for 1973–1978. Specific permits were not required for ocean dumping before 1973. Data for 1951–1968 may underestimate the amounts dumped. Totals for 1951–1968 include radioactive wastes and explosives. Totals for 1973–1978 include incinerated wood (18,000 tons in 1978).

Construction debris includes masonry, tile, stone, plastic, wiring, piping, shingles, glass, cinderblock, tar, tarpaper, plaster, vegetation, and excavation dirt.

Outfall pipes carrying wastes to sea through pipes often as long as 7 miles are located primarily near urban areas on the Pacific coast.

11-20
Oil spills in U.S. waters, 1971–1978

1971–1972: *Polluting incidents in and around U.S. waters, calendar year 1977*, U.S. Coast Guard (Washington, D.C., 1978), p. 23.
1973–1978: *Polluting incidents in and around U.S. waters, calendar year 1977 and 1978*, U.S. Coast Guard (Washington, D.C., 1980), p. 16.

Data are compiled from the U.S. Coast Guard's Pollution Incident Reporting System (PIRS).

Areas include the Great Lakes, ocean waters within 200 miles of the coast, and inland waters (river channels, harbors, etc.).

All major sources include vessels, land vehicles, nontransportation-related facilities, pipelines, marine facilities, and land facilities.

11-21
Toxic residues in coastal mussels and oysters, 1976

U.S. Environmental Protection Agency, Environmental Research Laboratory, Mussel Watch Program, Narragansett, R.I., unpublished data.

The EPA Mussel Watch Program measures toxic substances in bivalve molluscs. Four species are used: mussels are *Mytilus edulis* (west and east coasts) and *Mytilus californianus* (west coast); oysters are *Crassostrea virginica* (east and Gulf coasts) and *Ostrea equestris* (Gulf coast).

On the maps each circle represents the concentration in one sample at one station. A sample consists of about 25 mussels or oysters of the same species.

For 1976–1978, more than 100 samples have been analyzed each year.

Preliminary data for 1977 and 1978 show no marked changes of the substances reported.

The program will make a complete collection of samples again in 1981.

DDT refers to its derivatives DDD and DDE only.

All concentrations are measured in dry weight.

Chapter 12

Air Quality

Even the best known pollutants—sulfur dioxide, carbon monoxide, hydrocarbons, nitrogen oxides, and suspended particulates—occur naturally in the atmosphere. The air is said to be polluted when levels of these materials are harmful to life, cause damage to materials and structures, or impede visibility. Excessive levels are usually caused by chemicals, smoke, or toxic substances that are the byproducts of human activities. Wind and weather and natural chemical processes disperse and distribute the pollutants.

In the past, air pollution concerns centered on reducing soot and fly ash and other products of soft coal combustion. They have been significantly reduced by technological changes, environmental controls, and regulations. Emphasis is now on carbon monoxide, hydrocarbons, nitrogen dioxide, lead, and other combustion products of motor vehicles. Sulfur and nitrogen oxides, hydrocarbons, and toxic substances from industrial and commercial sources still cause considerable problems.

The Clean Air Act of 1963 set in motion a nationwide, Federal-State program to achieve acceptable air quality. Amended in 1970, the act required achievement of national air quality standards to protect human health by 1975. The 1977 amendments extended the deadline for attainment of ambient air quality standards in most areas to 1982. More stringent secondary standards to protect vegetation, aesthetic values, and property were to be achieved within a "reasonable time" as determined by the Environmental Protection Agency.

Air quality has been improving. The number of air pollution alerts has been reduced. The large amounts of chemical pollutants coming from industry have been reduced, and emissions from the worst offenders have been markedly curtailed.

But much remains to be done in cities and elsewhere. There is growing evidence that wilderness, parks, and other pristine areas may be threatened by air pollution.

457

12-1
Criteria and noncriteria air pollutants

Air pollutants range from completely odorless and colorless gases such as carbon monoxide to highly visible dense smoke and soot composed of suspended particulates emitted from smokestacks. Some pollutants are highly toxic in minute amounts—lead, asbestos, and beryllium. Others such as carbon monoxide can cause headaches, angina attacks, and at very high concentrations, death.

The U.S. Environmental Protection Agency classifies pollutants in two ways. Those for which the levels and length of exposure adversely affecting human health and welfare have been determined are the criteria pollutants. They include carbon monoxide, hydrocarbons, photochemical oxidants, sulfur dioxide, suspended particulates, nitrogen dioxide, and lead. National ambient air quality standards have been set for each of the criteria pollutants to protect human health and welfare.

Pollutants about which less is generally known and for which national ambient air quality standards have not been set are noncriteria pollutants. Their control is no less important, however. They include vinyl chloride, mercury, beryllium, asbestos, benzene, and other hazardous substances.

Pollutant	Standards		Characteristics	Principal sources	Principal effects
	Primary	Secondary			
Criteria pollutants					
Carbon monoxide (CO)	8 hour: 10 mg/m^3 (9 ppm) 1 hour: 40 mg/m^3 (35 ppm)	8 hour: 10 mg/m^3 (9 ppm) 1 hour: 40 mg/m^3 (35 ppm)	A colorless, odorless gas with a strong chemical affinity for hemoglobin in blood	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhaust; natural events such as forest fires, decomposition of organic matter	Health: Some reduced tolerance for exercise, impairment of mental function, impairment of fetal development, death at high levels. Other: Unknown
Hydrocarbons (HC)	3 hour (6 to 9 a.m.) 160 μg/m^3 (0.24 ppm)	3 hour (6 to 9 a.m.) 160 μg/m^3 (0.24 ppm)	Organic compounds in gaseous form, e.g., ethylene, acetylene	Incomplete combustion of fuels and other carbon-containing substances, such as in motor vehicle exhaust; processing, distribution, use of petroleum compounds such as gasoline, organic solvents; natural events such as forest fires, plant metabolism, atmospheric reactions	Health: Suspected contributor to cancer. Other: Major precursors in the formation of photochemical oxidants through atmospheric reactions
Photochemical oxidants (O_x)	1 hour: 240 μg/m^3 (0.12 ppm)	1 hour: 240 μg/m^3 (0.12 ppm)	Colorless, gaseous compounds which can comprise photochemical smog, e.g., ozone (O_3), peroxyacetyl nitrate, aldehydes, other compounds	Atmospheric reactions of chemical precursors under the influence of sunlight	Health: Aggravation of respiratory and cardiovascular illnesses, irritation of eyes and respiratory tract, impairment of cardiopulmonary function. Other: Deterioration of rubber, textiles, and paints, impairment of visibility, leaf injury, reduced growth, premature fruit, leaf drop in plants
Sulfur dioxide (SO_2)	Annual (arithmetic mean) 80 μg/m^3 (0.03 ppm) 24 hour: 365 μg/m^3 (0.14 ppm)	3 hour: 1300 μg/m^3 (0.5 ppm)	A colorless gas with a pungent odor. SO_2 can oxidize to form sulfur trioxide, which forms sulfuric acid with water	Combustion of sulfur-containing fossil fuels, smelting of sulfur-bearing metal ores, industrial processes, volcanic eruptions	Health: Aggravation of respiratory diseases, including asthma, chronic bronchitis, emphysema, reduced lung function, irritation of eyes, respiratory tract, increased mortality. Other: Corrosion of metals, deterioration of electrical contacts, paper, textiles, leather, finishes and coatings, building stone, formation of acid rain, leaf injury, reduced growth in plants, impairment of visibility

Pollutant	Standards Primary	 Secondary	Characteristics	Principal sources	Principal effects
Total suspended particulates (TSP)	Annual (geometric mean): 75 $\mu g/m^3$ 24 hour: 260 $\mu g/m^3$	Annual (geometric mean): 60 $\mu g/m^3$ 24 hour: 150 $\mu g/m^3$	Any solid or liquid particles (diameter ranging from 0.3 to 100 microns) dispersed in the atmosphere, such as dust, pollen, ash, soot, metals, various chemicals	Stationary combustion, especially of solid fuels; construction activities; industrial processes; atmospheric chemical reactions; smoking tobacco; forest fires, wind erosion, volcanic eruptions	Health: Directly toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory or cardiorespiratory symptoms, increased cough, chest discomfort; increased mortality. Other: Soiling, deterioration of building materials, other surfaces, impairment of visibility, cloud formation; interference with plant photosynthesis
Nitrogen dioxide (NO_2)	Annual (arithmetic mean): 100 $\mu g/m^3$ (0.05 ppm)	Annual (arithmetic mean): 100 $\mu g/m^3$ (0.05 ppm)	At high concentrations, a brownish-red gas with a pungent odor, often formed from oxidation of nitric oxide	Motor vehicle exhaust, high-temperature stationary combustion, atmospheric reactions	Health: Aggravation of respiratory illnesses. Other: Fading of paints, dyes, impairment of visibility, reduced growth, premature leaf drop in plants, formation of acid rain
Lead	3 month: 1.5 $\mu g/m^3$	3 month: 1.5 $\mu g/m^3$	A nonferrous heavy metal occurring in air as vapor, aerosol, or dust	Naturally occurring; lead mining, smelting, processing; motor vehicle emissions; manufacture of lead products (e.g., batteries)	Health: Accumulation in body organs, anemia; kidney damage; central nervous system damage. Other: Unknown
Noncriteria pollutants					
Asbestos	8 hour: 0.5 fibers/cc		Naturally occurring fibrous silicates, used in plaster, floor tiles, brake lining; occurs as fine particulate	Asbestos mining, processing; spraying of fire proofing insulation, attrition of brake linings; building demolition; use of certain crushed stone in road paving	Health: Fibrosis, calcification, cancer of the lungs, pleural cavity. Other: Unknown
Vinyl chloride	8 hour: 1 ppm		A gas produced commercially from ethylene	Production of plastics, polyvinyl chloride	Health effects from occupational exposure: Damage to liver and pulmonary functions, acute intoxication, acroosteolysis. Other: Unknown
Metals (arsenic, beryllium, cadmium, chromium, mercury, nickel, vanadium)	8 hour: 2 $\mu g/m^3$ (beryllium) 10 hour: 0.01 mg/m^3 (mercury)		Naturally occuring; in air is vapor, aerosol, or dust	Mining, smelting, combustion of fossil fuels, especially coal	Health: Accumulation in body organs; skin, respiratory cancer; impairment of nervous system. Other: Toxic to fish, wildlife; leaf injury, reduced plant growth
Respirable particulates	None		Any solid or liquid particles (diameter less than 0.3 microns) dispersed in the atmosphere, such as dust, pollen, ash, soot, metals, various chemicals	Stationary combustion, especially of solid fuels; construction activities; industrial processes; atmospheric chemical reactions; smoking tobacco; forest fires, wind erosion, volcanic eruptions	Health: Directly toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory or cardiorespiratory symptoms; increased cough, chest discomfort; increased mortality. Other: Unknown
Cobalt-60, iodine-137, strontium-90, other radioactive substances			Gaseous, liquid, or solid substances giving off high-energy radiation	Rocks, soils, cosmic rays; nuclear weapons testing; nuclear power generation; uranium mining, refining, machining operations	Health: Leukemia, bone cancer, genetic damage. Other: Degradation of plastics, materials; leaf injury, reduced plant growth

12-2
Pollutant Standards Index values, pollutant levels, and health effects

One measure of air quality is the Pollutant Standards Index. It is a highly summarized health-related index based on five of the criteria pollutants: carbon monoxide, ozone, sulfur dioxide, total suspended particulates, and nitrogen dioxide. The PSI for one day will rise above 100 in a Standard Metropolitan Statistical Area when one criteria pollutant at one station reaches a level judged to have adverse short-term effects on human health.

				Pollutant level					
PSI index value	Air quality level	Cautionary statements	Health effect label	TSP (24-hour) $\mu g/m^3$	SO_2 (24-hour) $\mu g/m^3$	CO (8-hour) $\mu g/m^3$	O_3 (1-hour) $\mu g/m^3$	NO_2 (1-hour) $\mu g/m^3$	General health effects
500	Significant harm			1000	2620	57.5	1200	3750	
		All persons should remain indoors, keeping windows and doors closed. All persons should minimize physical exertion and avoid traffic							Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity
400	Emergency		Hazardous (PSI > 300)	875	2100	46.0	1000	3000	
		Elderly and persons with diseases should stay indoors and avoid physical exertion. General population should avoid outdoor activity							Premature onset of some diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons
300	Warning			625	1600	34.0	800	2260	
		Elderly and persons with existing heart and lung disease should stay indoors and reduce physical activity	Very unhealthful (PSI = 200 to 300)						Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population
200	Alert			375	800	17.0	400	1130	
		Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity	Unhealthful (PSI = 100 to 200)						Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population
100	NAAQS[a]			260	365	10.0	240	(b)	
			Moderate (PSI = 50 to 100)						
50	50% of NAAQS[a]			75[c]	80[c]	5.0	120	(b)	
			Good (PSI = 0 to 50)						
0				0	0	0	0	(b)	

[a] NAAQS = National Ambient Air Quality Standard.

[b] There are no index values reported at concentrations below those specified by Alert criteria.

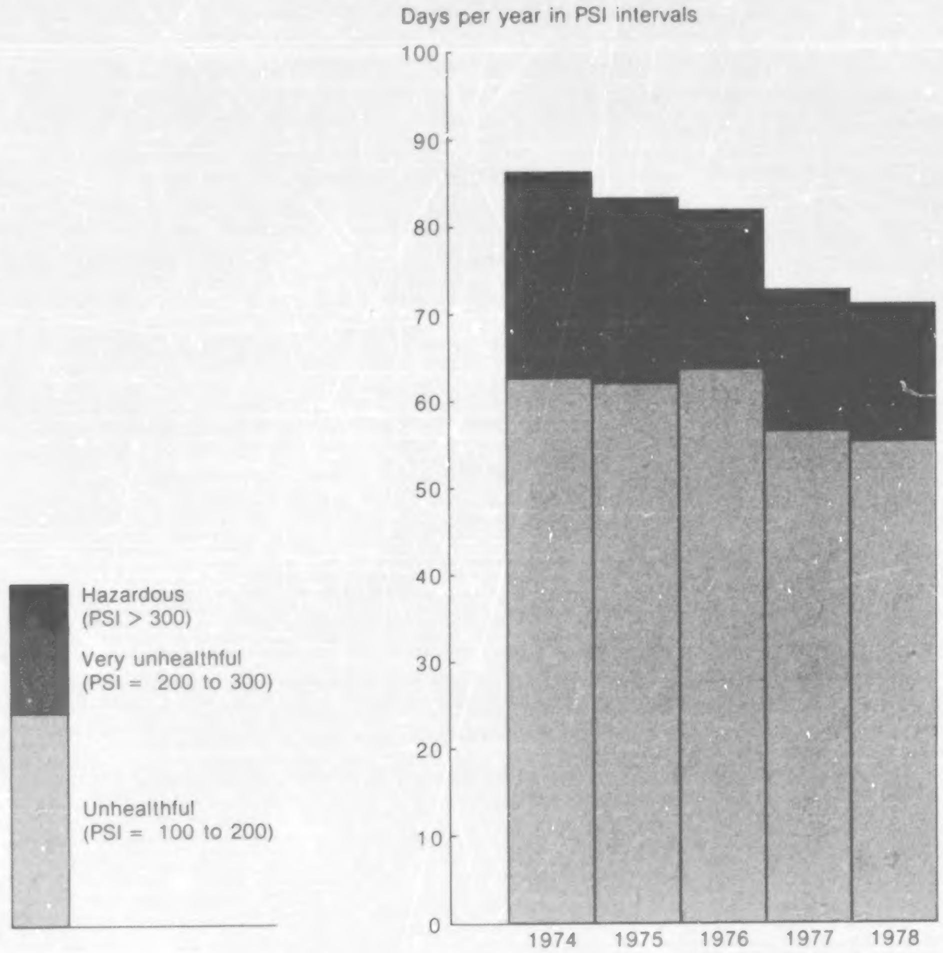
[c] Annual primary NAAQS

12-3

Average Pollutant Standards Index in 23 Standard Metropolitan Statistical Areas, 1974–1978

Air quality in many major metropolitan areas is improving. The average number of days for 23 major metropolitan areas in which the air was unhealthful or worse decreased from 86 in 1974 to 72 in 1978, an improvement of 16%. More significantly, the pollution is less severe—the number of days when the PSI was very unhealthful or hazardous decreased 33%.

Metropolitan areas are a long way from achieving the goal of protecting human health: no more than one day per year with a PSI above 100.

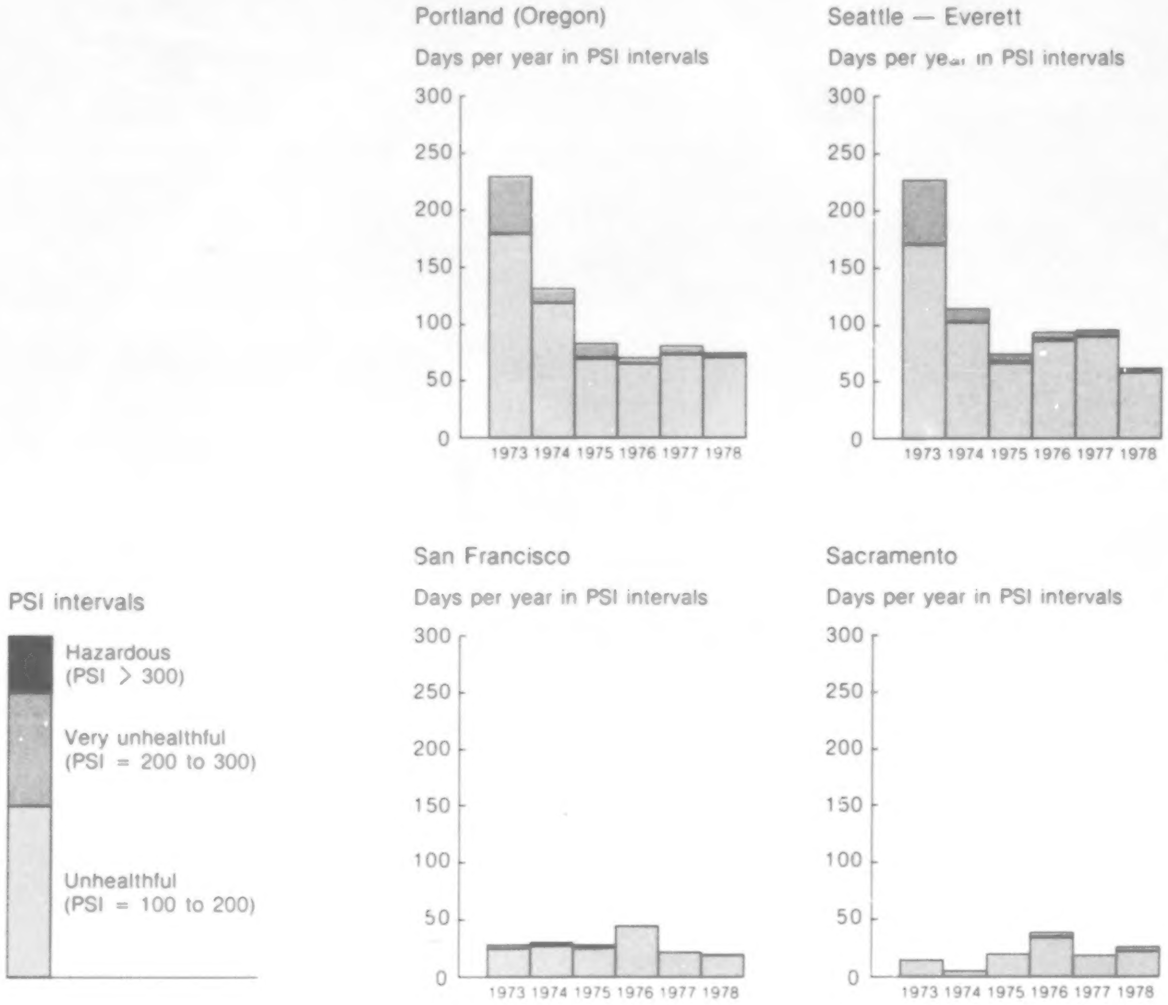


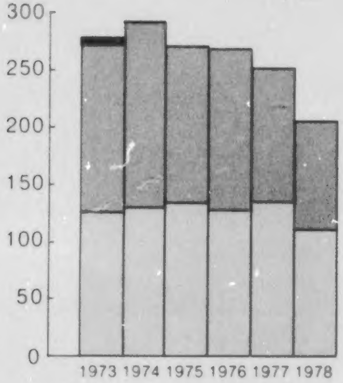
464

465

12-4
Pollutant Standards Index in 24 Standard Metropolitan Statistical Areas, 1973-1978

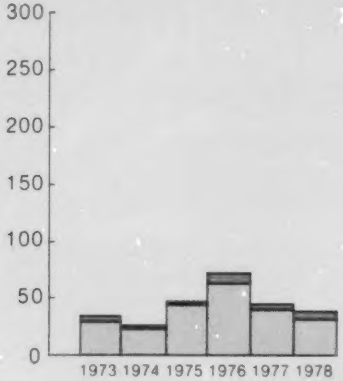
Air pollution in metropolitan areas, as measured by the Pollutant Standards Index, varies widely. Of the 24 SMSAs for which at least 5 years' comparable data were available, Los Angeles registered the most unhealthful days. Carbon monoxide and photochemical oxidants, emitted primarily by motor vehicles, were generally responsible for raising the PSI above 100 in these areas.





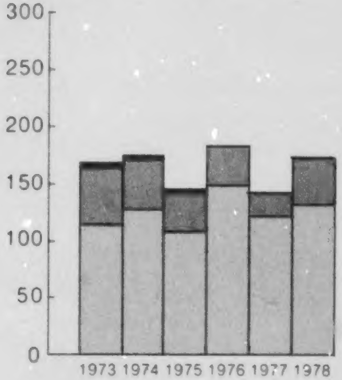
Los Angeles

Days per year in PSI intervals



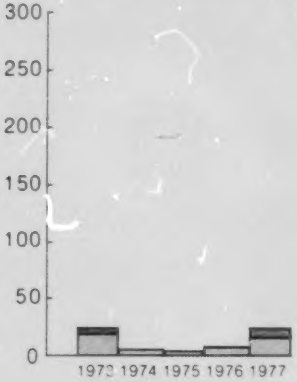
San Diego

Days per year in PSI intervals



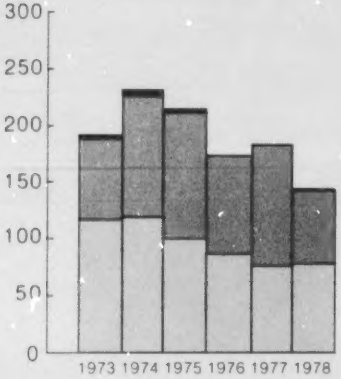
Denver

Days per year in PSI intervals



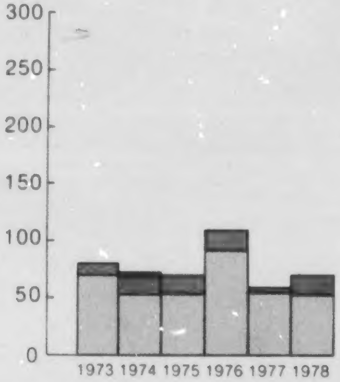
Kansas City

Days per year in PSI intervals



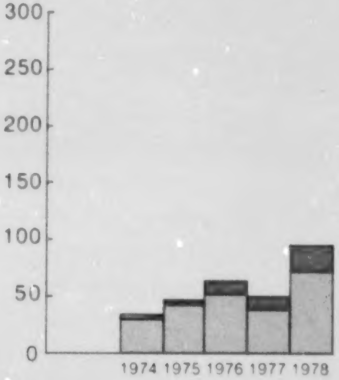
San Bernardino —
Riverside — Ontario (California)

Days per year in PSI intervals



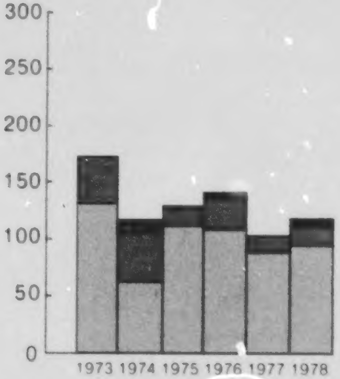
Salt Lake City

Days per year in PSI intervals



Houston

Days per year in PSI intervals



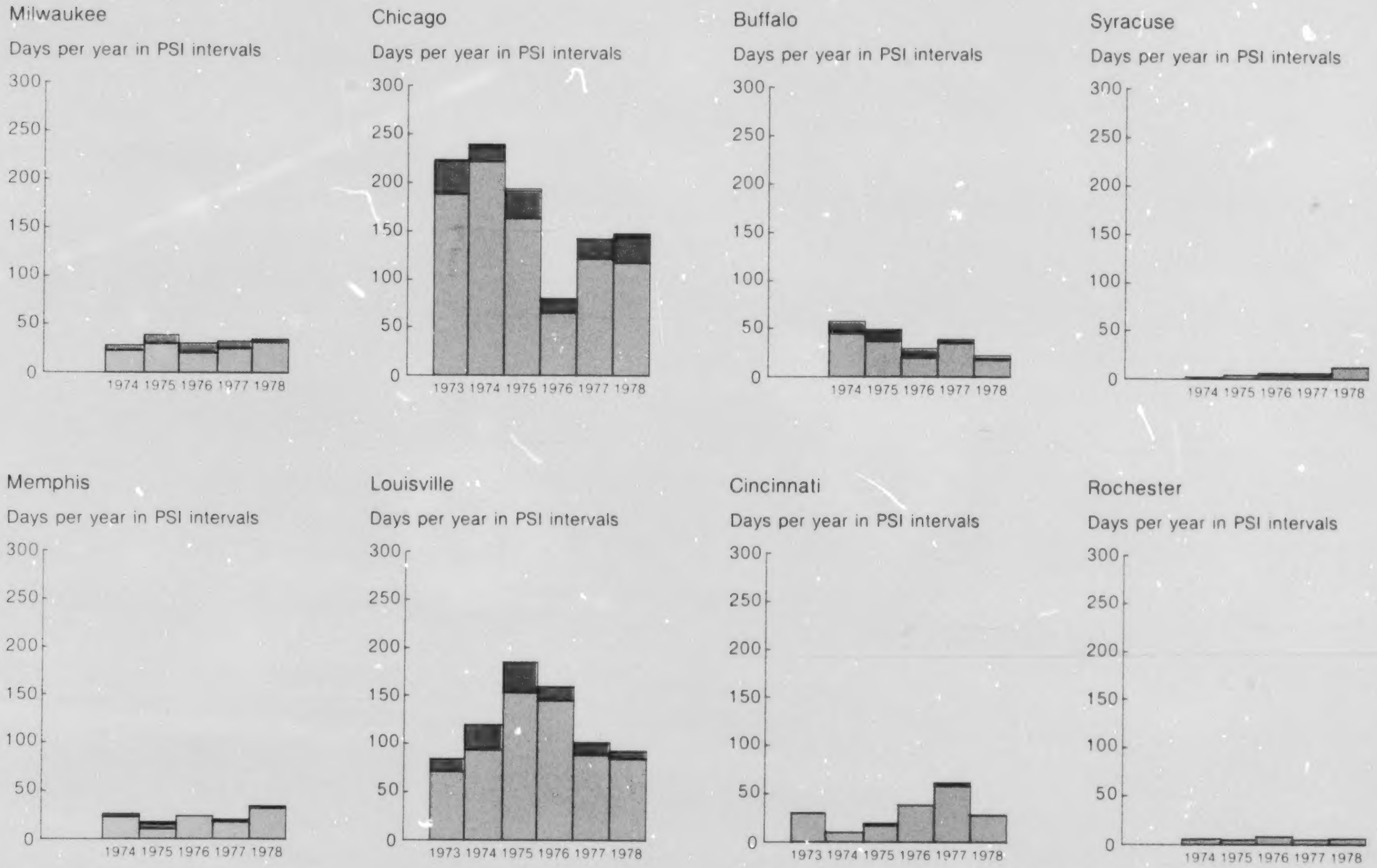
St. Louis

Days per year in PSI intervals

468

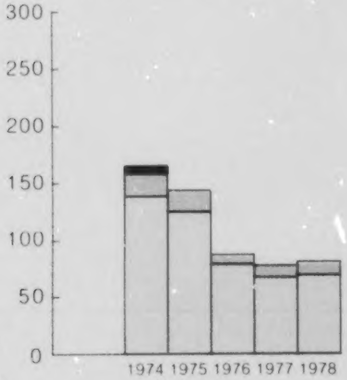
469

12-4 cont.
Pollutant Standards Index in 24 Standard Metropolitan Statistical Areas, 1973–1978



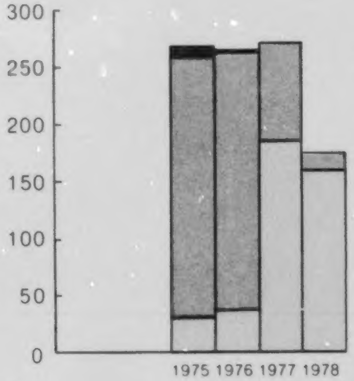
Philadelphia

Days per year in PSI intervals

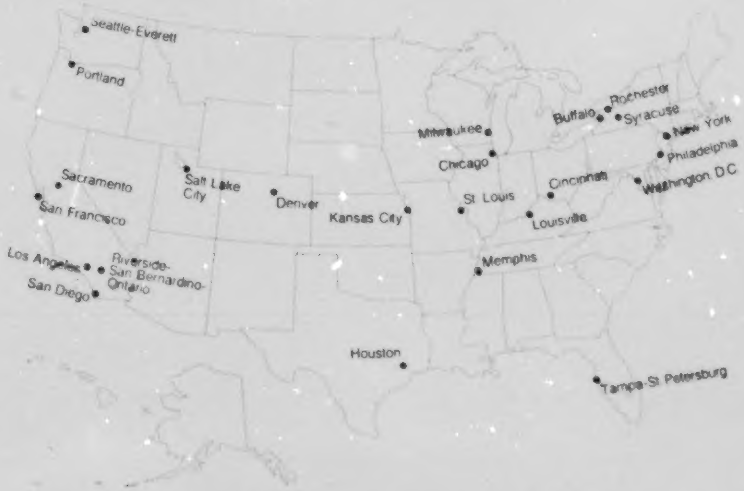


New York

Days per year in PSI intervals

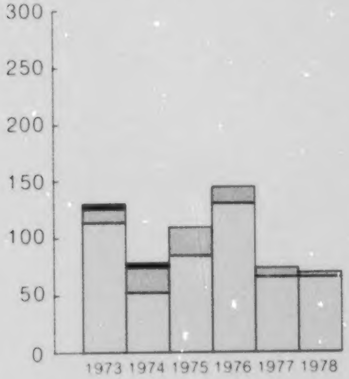


Selected SMSAs


Seattle-Everett
Portland
Sacramento
San Francisco
Los Angeles
Riverside-San Bernardino-Ontario
San Diego
Salt Lake City
Denver
Kansas City
Houston
Milwaukee
Chicago
St Louis
Memphis
Cincinnati
Louisville
Buffalo
Rochester
Syracuse
New York
Philadelphia
Washington D.C.
Tampa-St Petersburg

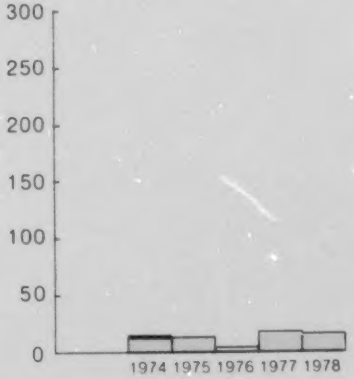
Washington, D.C.

Days per year in PSI intervals



Tampa — St. Petersburg

Days per year in PSI intervals



PSI intervals

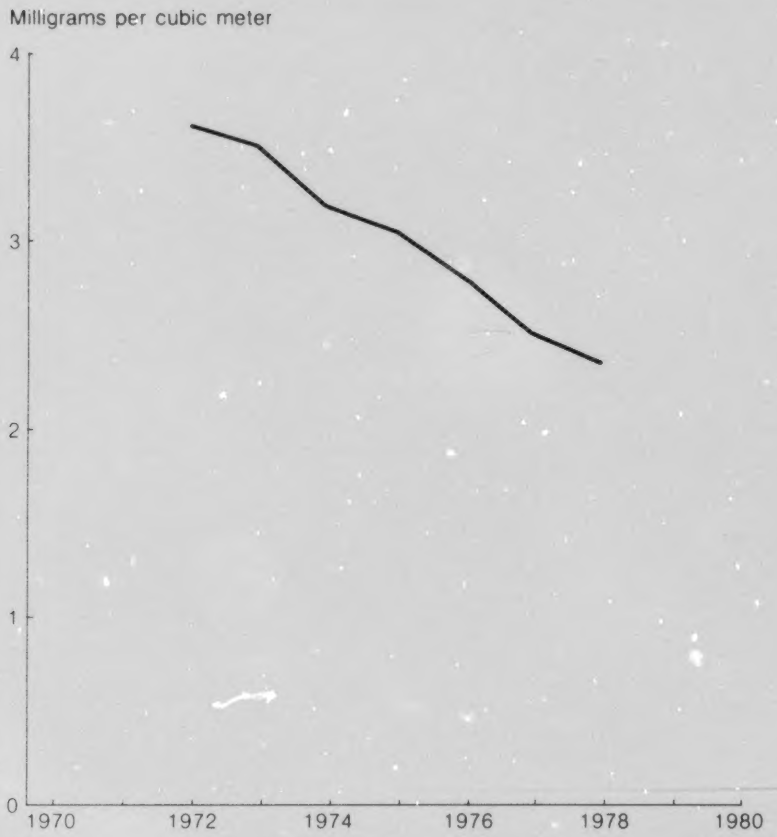
■ Hazardous (PSI > 300)

▨ Very unhealthful (PSI = 200 to 300)

□ Unhealthful (PSI = 100 to 200)

12-5

National ambient carbon monoxide concentrations, 1972–1978

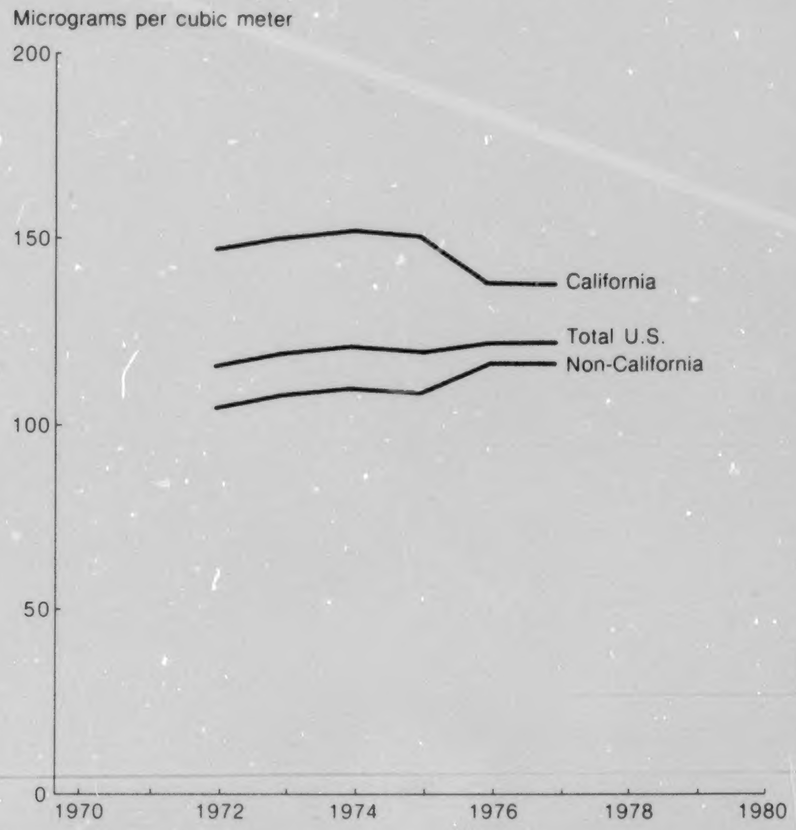


Carbon monoxide is the most ubiquitous air pollutant. CO is formed from the incomplete combustion of fuels and other carbon-containing substances. CO concentrations are usually highest in downtown areas of major cities, where tall buildings trap motor vehicle exhaust fumes.

Ambient levels of CO generally improved during the 1970s. Measured at 183 monitoring sites, carbon monoxide concentrations declined 35% between 1972 and 1978.

12-6

National ambient ozone concentrations, 1972–1977

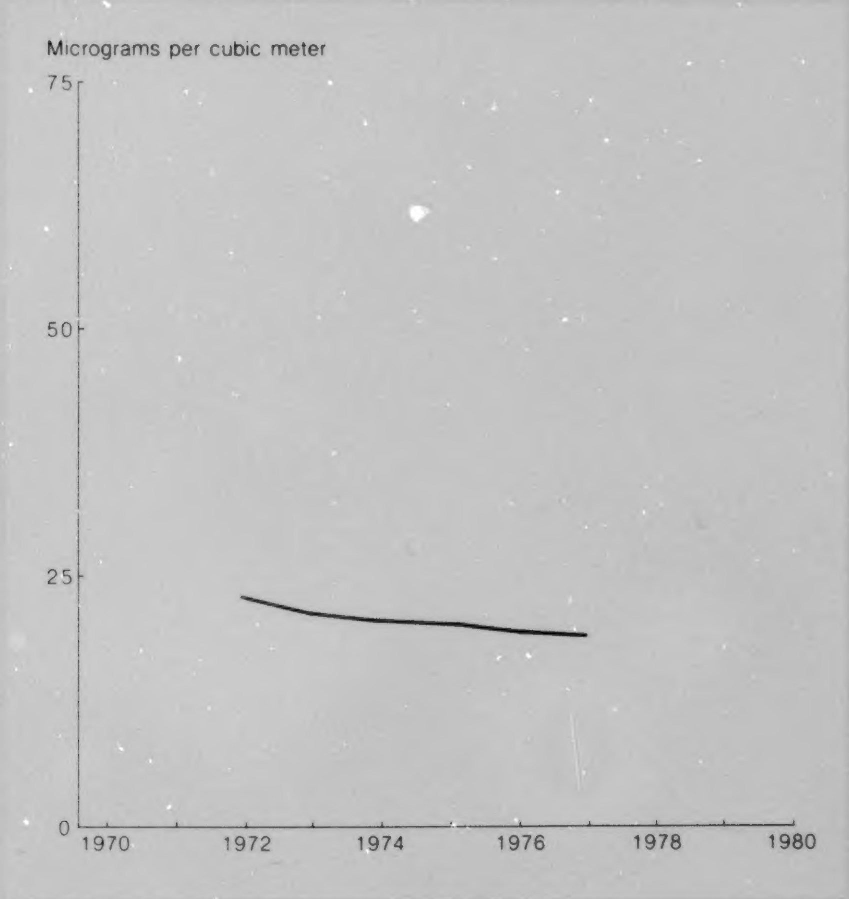


Photochemical oxidants form when hydrocarbons and nitrogen oxides combine in the presence of sunlight. The result is photochemical smog—ozone, peroxyacetyl nitrate, acrolein, and a host of other undesirable products that irritate the eye and cause respiratory difficulties.

Smog, particularly in the Los Angeles basin, has been recognized as an air pollution problem for years. Since the early 1960s, the amount of photochemical oxidants in the air has decreased substantially, but outside California, where the problem has been less severe (and data are fewer), concentrations have increased.

12-7

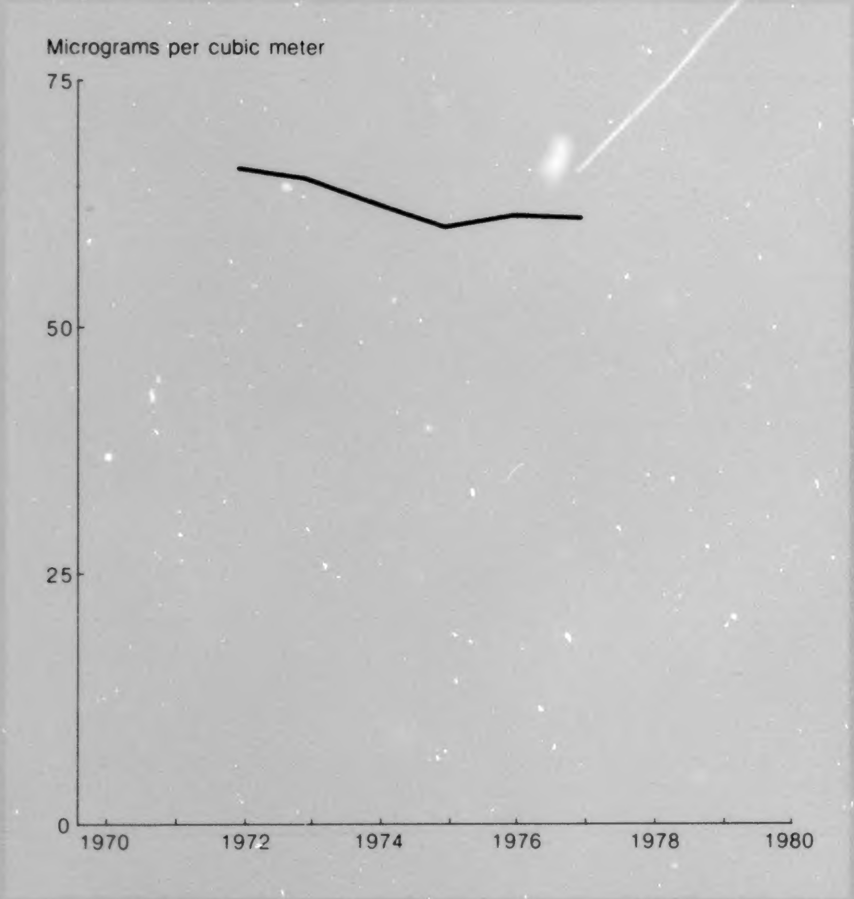
National ambient sulfur dioxide concentrations, 1972-1977



Nationally, sulfur dioxide levels in the air decreased 16% between 1972 and 1977. Almost all cities are now able to maintain levels well below the ambient air quality standard of 80 micrograms per cubic meter.

12-8

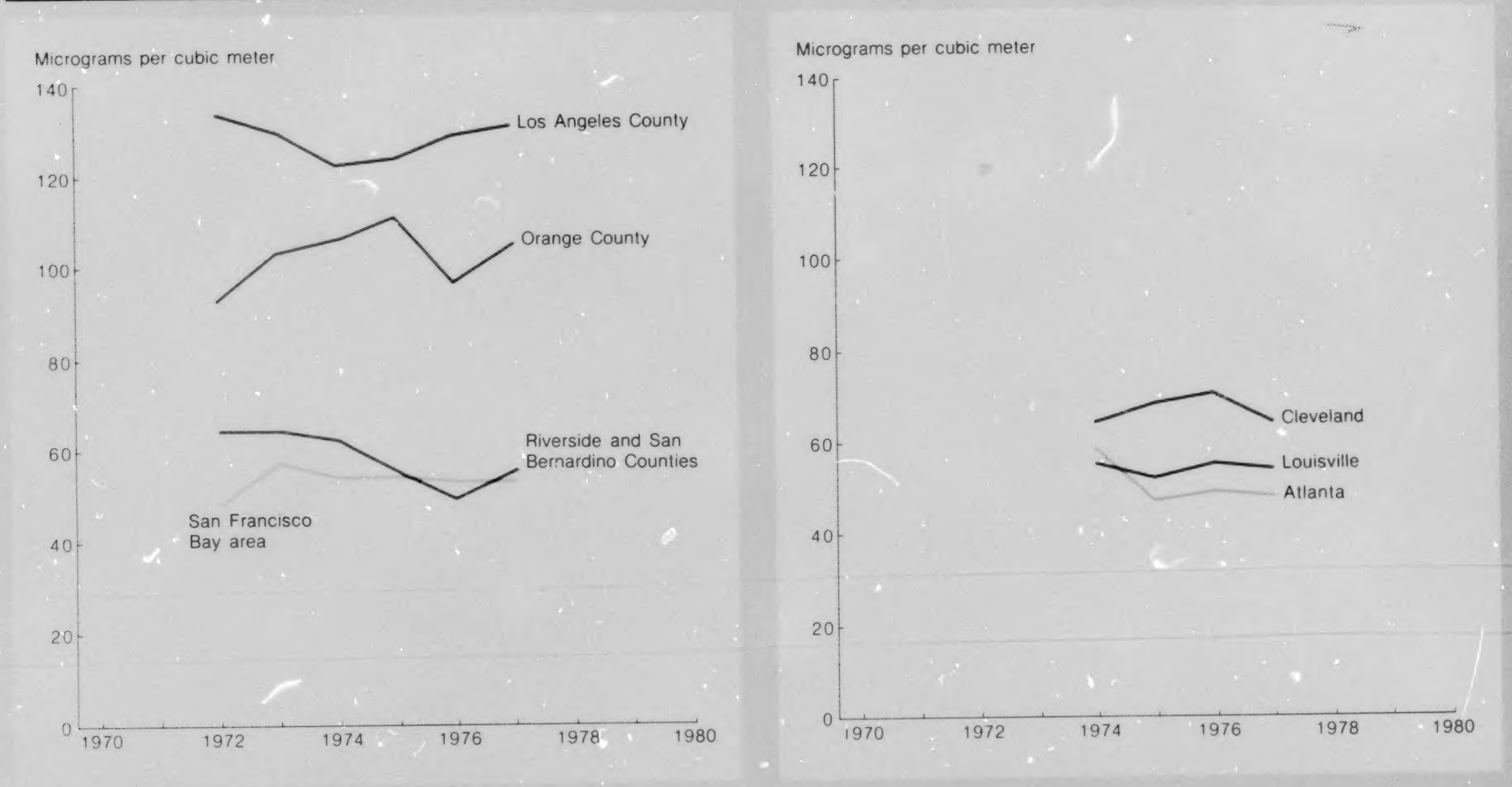
National ambient total suspended particulate concentrations, 1972-1977



Total suspended particulate concentrations decreased by 8% between 1972 and 1977. Most changed were the areas with very high readings. For sites with total suspended particulate concentrations exceeding the annual standard of 75 micrograms per cubic meter, 77% showed improvement since 1972.

12-9

Ambient nitrogen dioxide concentrations, selected areas, 1972–1977



The fifth criteria pollutant, nitrogen dioxide, is not well monitored, and national data are not available.

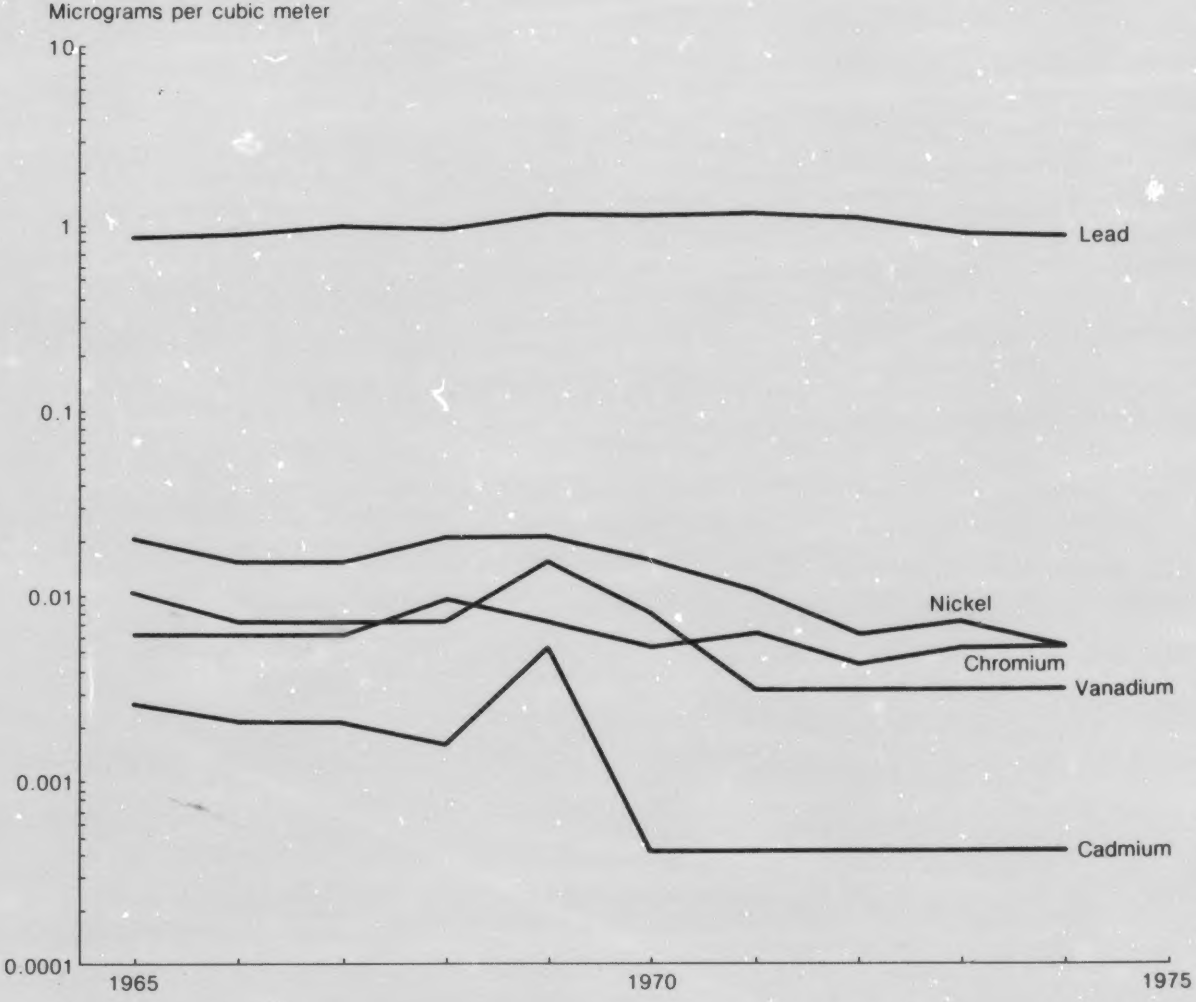
Of the seven metropolitan areas for which extensive data are available, Los Angeles registered the highest levels.

12-10
Ambient trace metal concentrations in 92 urban areas, 1965–1974

Other pollutants are released into the atmosphere daily. Most are not harmful to humans and other life at concentrations that are usually found in the air. But the amounts breathed added to the amounts consumed in food and water can be harmful.

Some of these substances are metals. Lead, for example, can cause poisoning. Nickel, cadmium, chromium, and vanadium are all implicated as carcinogens. These elements are also catalysts for the atmospheric conversion of sulfur dioxide to sulfates—which are believed to aggravate respiratory disease, reduce lung function, increase mortality, form acid rain, and reduce plant growth.

Metal concentrations have generally declined in the urban areas for which data are available. The decrease in lead levels since 1970 is a function primarily of lead-free gasoline use. Cadmium reductions may be caused by control of particulate emissions from the metals industries, and reductions of nickel and vanadium are a function of the removal of sulfur in fuel oils and the use of low sulfur oil.

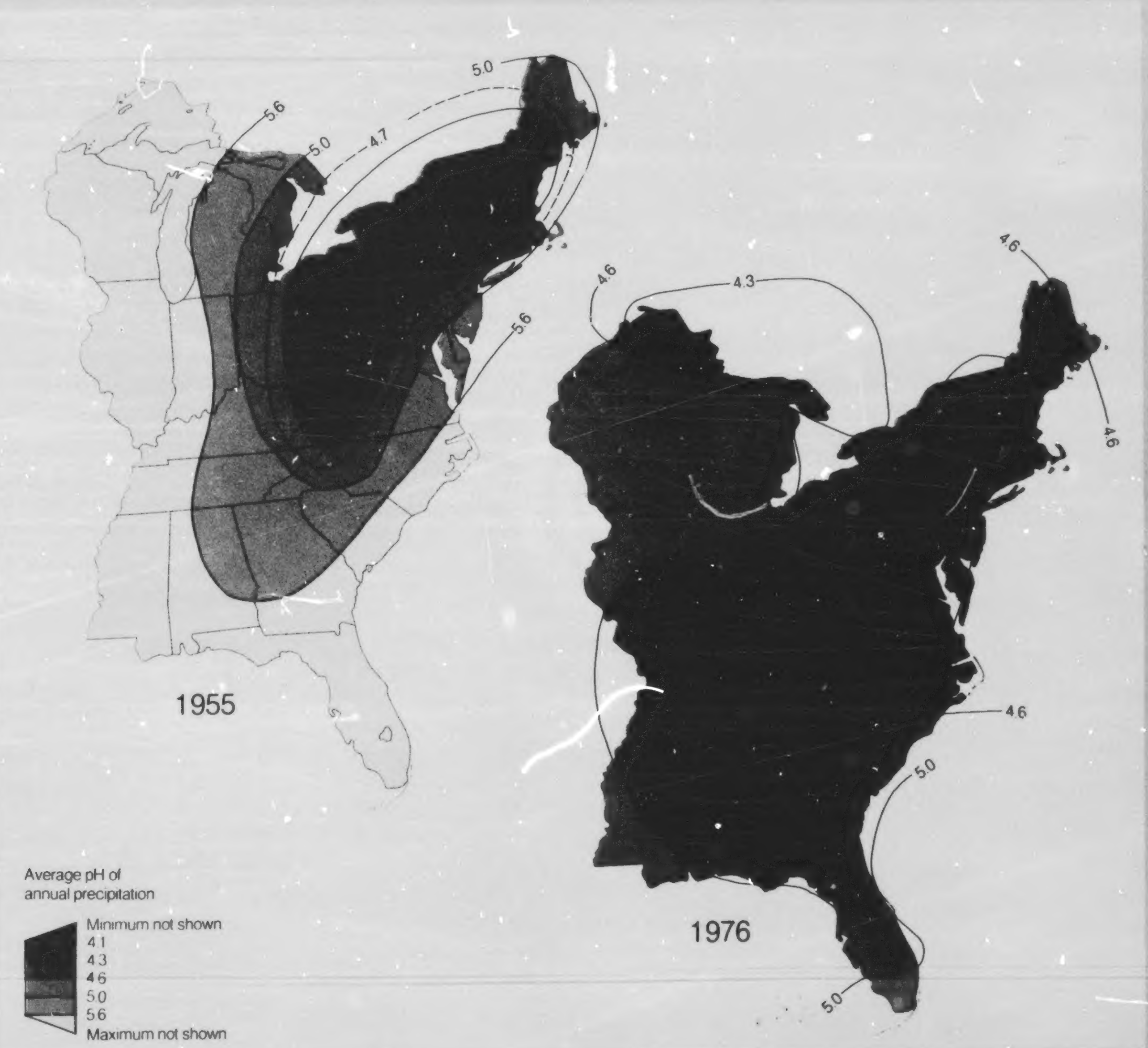


12-11
Acid precipitation in the eastern United States, 1955–1976

Although clean air goals began with concern for human health, they also encompass concern for the long-term effects of air pollutants on human welfare and on the normal functioning of the ecosystem. Some long-term effects are becoming apparent. Acid precipitation is one.

Rain and snow that are very acidic are the result of high concentrations of sulfur dioxide and nitrogen oxide which have been converted to sulfuric and nitric acids in the air. Acid rain adversely affects materials, vegetation, and agricultural and forest yields in areas far from sources of the emissions. Most noticeably, acid precipitation is creating such highly acidic conditions in small alpine lakes that fish and other aquatic life cannot survive.

The acidity of precipitation is increasing. Highest in the Northeast, it is spreading into the Midwest and South. pH is a measure of the hydrogen ion activity in water. A pH of 7 indicates neutrality, below 7 is acid, and above 7 is alkaline. A decline from pH of 6.0 to 5.0 is equivalent to a 10-fold increase in acidity.


5.6
5.0
4.7
5.0
5.6
1955
4.6
4.3
4.6
4.6
4.6
5.0
5.0
1976
Average pH of
annual precipitation
Minimum not shown
4.1
4.3
4.6
5.0
5.6
Maximum not shown

12-12

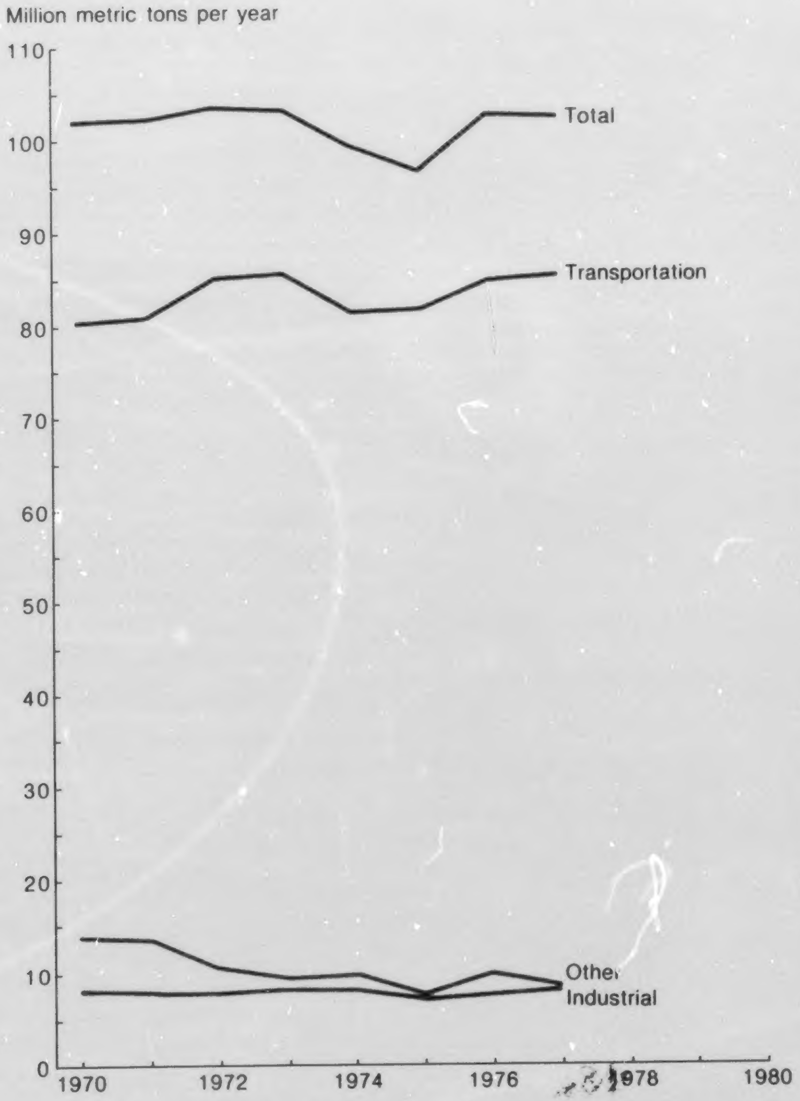
Carbon monoxide emissions, 1970–1977

Measures of ambient air quality indicate conditions of the air. Measures of emissions indicate materials going into the air.

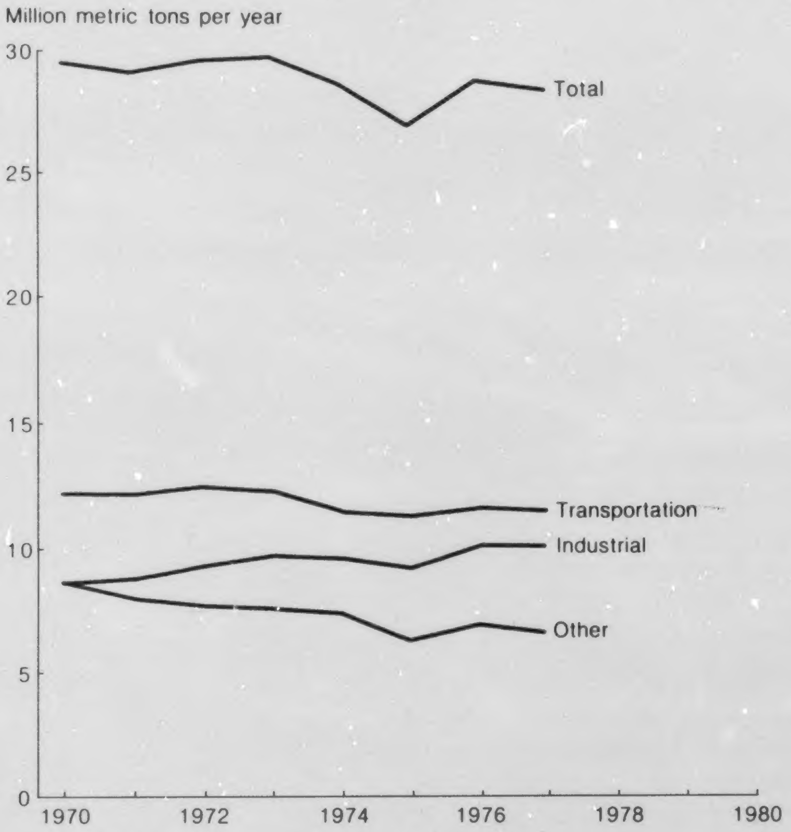
To limit pollution, steps must be taken to prevent emissions of materials at their sources. Sources may be mobile or stationary. There are about 150 million motor vehicles and more than 200,000 stationary sources (power plants and other industries, solid waste dumps, and commercial establishments, for example), at least 23,000 of them major pollutors. Each major stationary source emits more than 100 tons of air pollutants each year. Other stationary sources are forests and structural fires.

Automobiles produce the largest amount of carbon monoxide. Reduction of CO emissions from late model year automobiles has been offset by a 34% increase since 1970 in the number of vehicles on the road and by an increase in the number of miles driven. Without pollution controls, the total carbon monoxide emitted would have increased significantly.

Overall, CO emissions have changed little since 1970.



12-13
Hydrocarbon emissions, 1970–1977

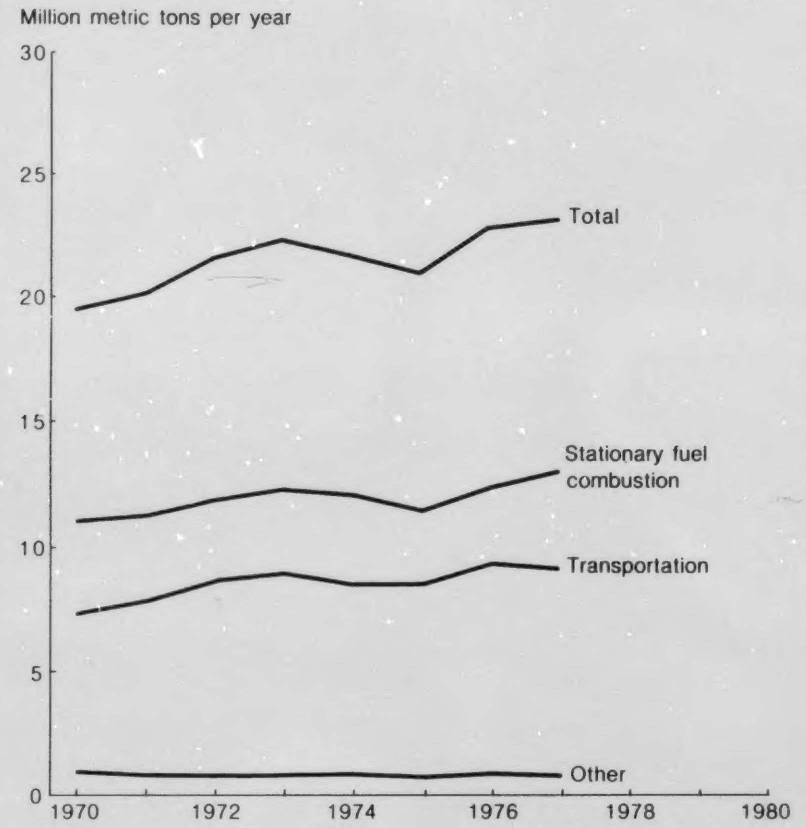


Hydrocarbon sources include motor vehicles, industrial processes, gas stations, household organic solvents, even natural sources.

Since 1970, total hydrocarbon emissions have dropped only slightly. The decline in transportation-related emissions is related to pollution controls on vehicles. The increased industrial emissions in 1976 reflect increased production since 1975.

486

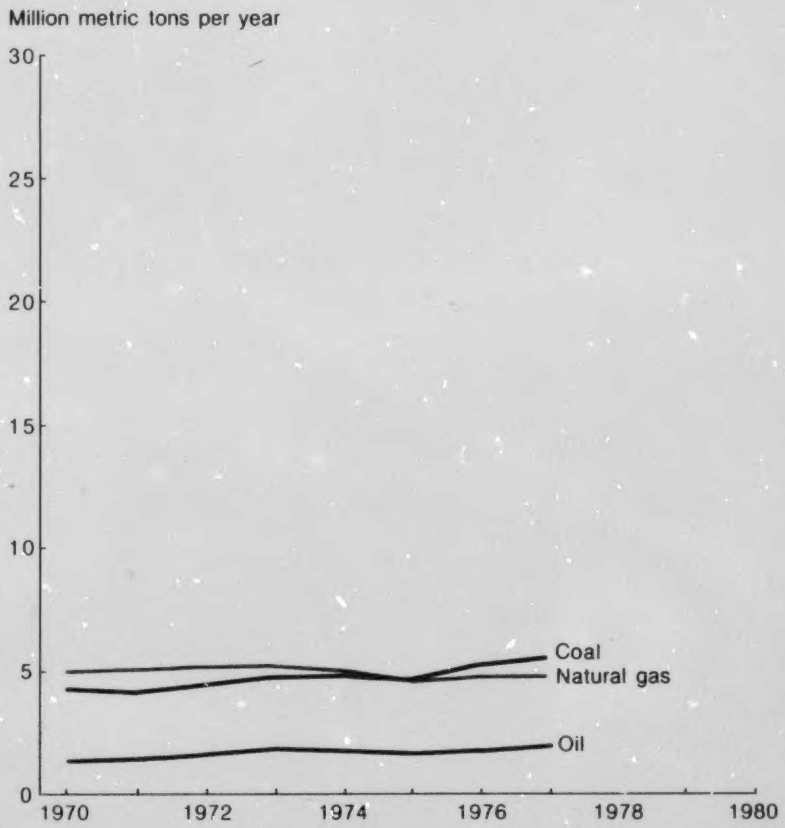
12-14
Nitrogen oxide emissions, 1970–1977



Nitrogen oxides come from both stationary sources—electric utilities, factories, residences—and mobile sources. Levels have increased 18% since 1970 because highway travel and use of electricity increased.

The pollution control equipment on motor vehicles produced before 1975 did not substantially affect emissions. Levels are expected to change when emission control devices are required on all new motor vehicles.

12-15
Nitrogen oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977

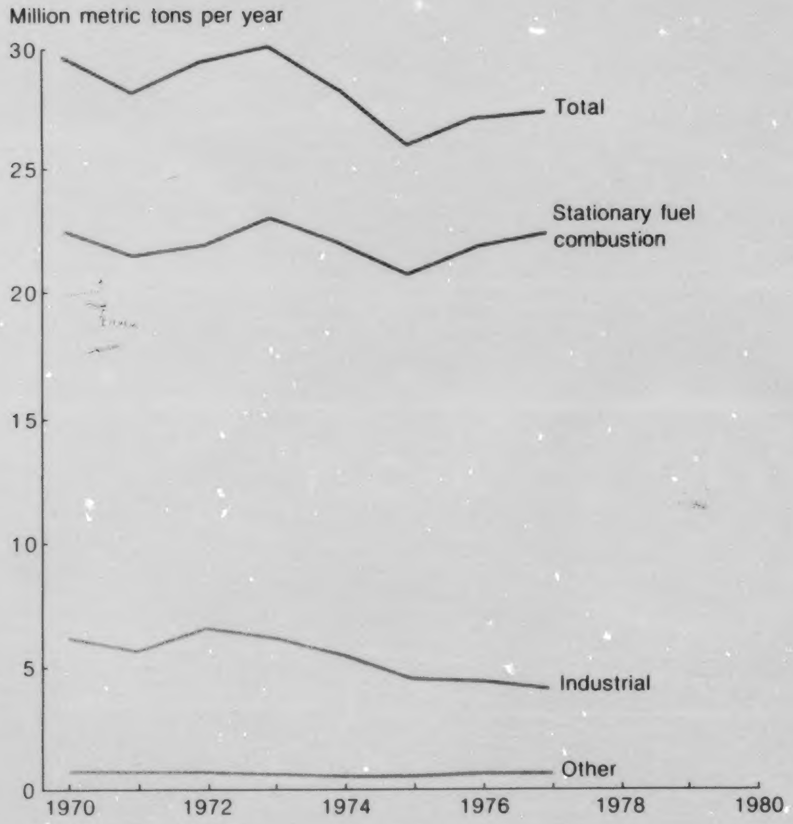


Use of coal to fire boilers for generation of electricity is primarily responsible for increased nitrogen oxide emissions.

487

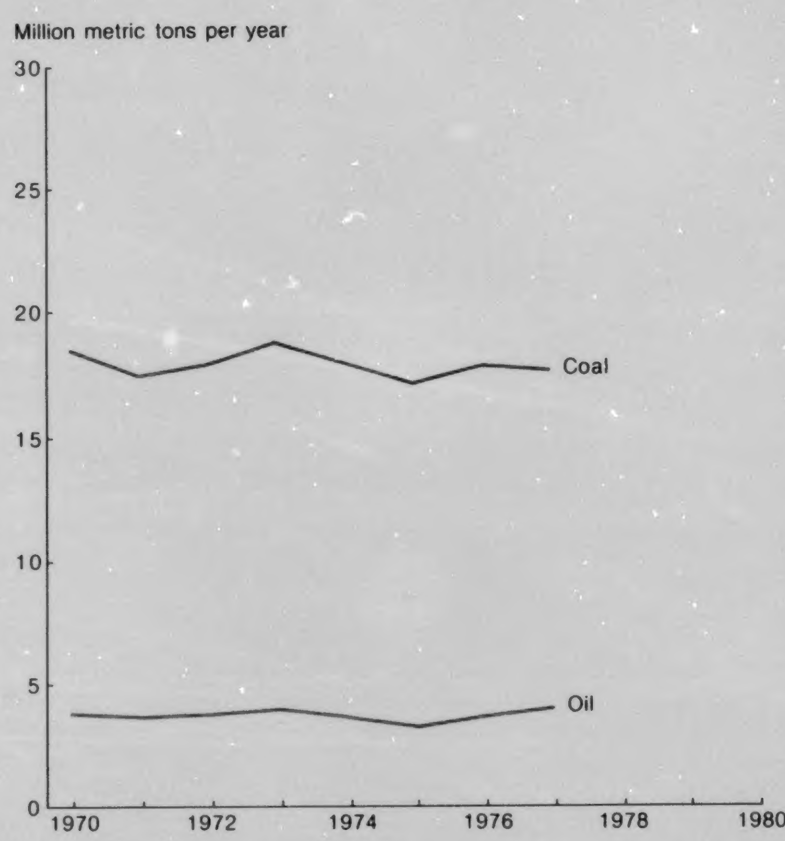
488

12-16
Sulfur oxide emissions, 1970–1977



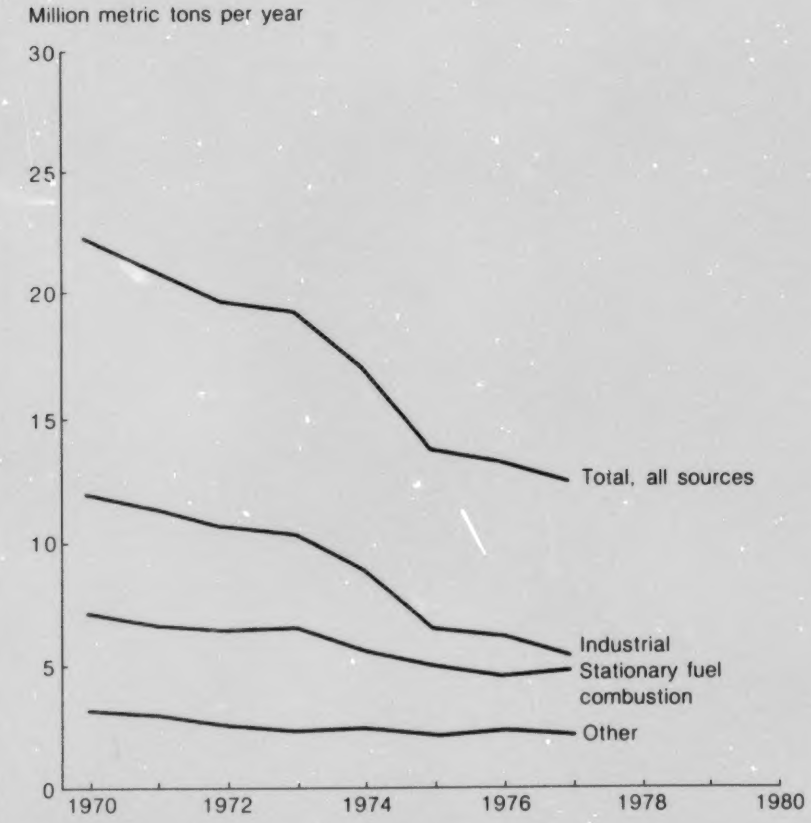
Sulfur oxides are emitted during combustion of coal and residual fuel oil, from metals smelting, and in the production of such basic chemicals as sulfuric acid. Emissions have declined about 8% since 1970, primarily because of controls applied by the smelting and chemical industries.

12-17
Sulfur oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977



Electric utilities used 49% more coal and 86% more oil in 1977 than in 1970. Just to maintain sulfur oxide emissions at their 1970 level required use of low-sulfur coal and oil and the control of stack gases.

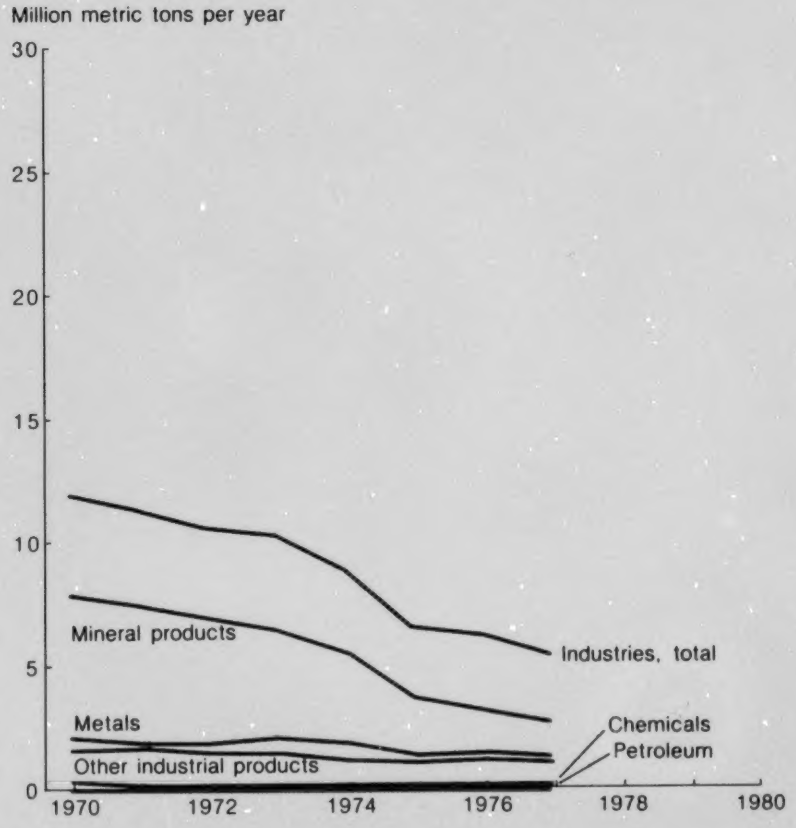
12-18
Total suspended particulate emissions, 1970–1977



Suspended particulates are primarily emitted during the combustion of fossil fuels. Since 1970, total suspended particulate emissions have been reduced more than 40%. The reduction comes from use of control equipment in coal-fired electric utilities and in industry (industry now removes approximately 88% of the particulates that it produces); use of less coal in small industries; and from less open burning of solid wastes.

491

12-19
Total suspended particulate emissions from industrial sources, 1970–1977



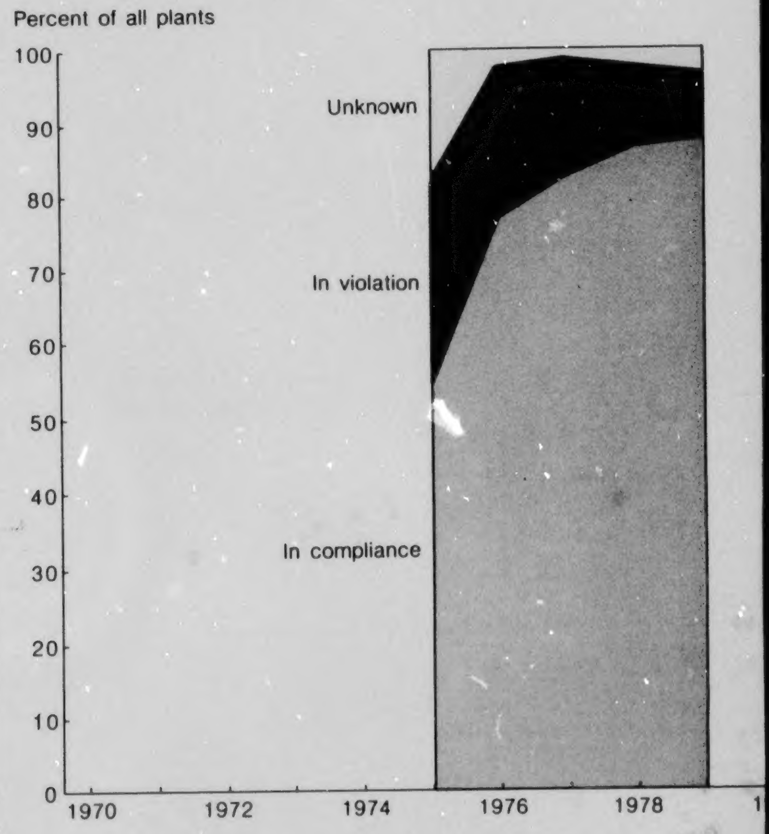
Control equipment in the mineral products industry—stone, clay, lime, cement, and glass, for example—is responsible for the big reduction in total suspended particulate emissions.

492

12-20

Compliance status of major stationary air pollution sources, 1975–1979

Most major industrial sources of air pollution are in compliance with Federal and State standards. In mid-1979, 88% were meeting emission limitations, and 4% had plans or were purchasing equipment to do so.

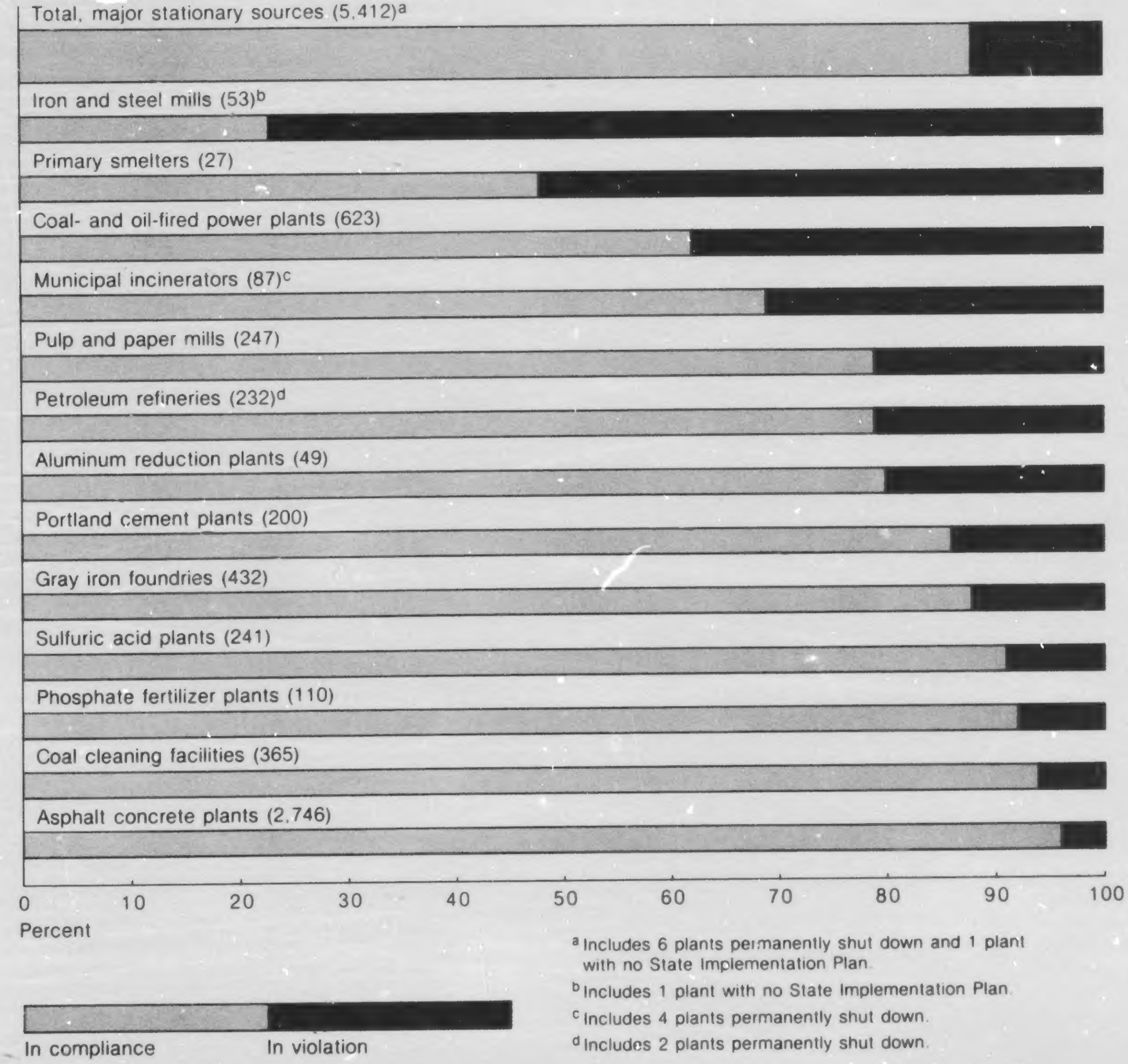


493

12-21

Compliance status of major stationary air pollution sources, by industry, 1979

Of 13 major industries, the iron and steel industry has the lowest percentage of plants in compliance with emission limitations.



[a] Includes 6 plants permanently shut down and 1 plant with no State Implementation Plan.

[b] Includes 1 plant with no State Implementation Plan.

[c] Includes 4 plants permanently shut down.

[d] Includes 2 plants permanently shut down.

Sources and technical notes

12-1
Criteria and noncriteria air pollutants

Environmental quality—1975, Council on Environmental Quality (Washington: USGPO, 1975), pp. 300–303, 328–331.

Air quality criteria for ozone and other photochemical oxidants, U.S. Environmental Protection Agency (Washington: USGPO, 1979).

Air quality criteria for lead, U.S. Environmental Protection Agency (Washington: USGPO, 1978).

Air quality criteria for carbon monoxide, U.S. Environmental Protection Agency (Washington: USGPO, 1980).

"Air quality criteria for oxides of nitrogen," U.S. Environmental Protection Agency, draft, June 1979.

U.S. Environmental Protection Agency, unpublished data.

12-2
Pollutant Standards Index values, pollutant levels, and health effects

Guidelines for public reporting of daily air quality—Pollutant Standards Index (PSI), U.S. Environmental Protection Agency (Research Triangle Park, N.C., 1976), EPA-450/2-76-013, OAQPS 1.2-044, table 3, p. 10.

12-3
Average Pollutant Standards Index in 23 Standard Metropolitan Statistical Areas, 1974–1978

1974–1978: *Environmental quality—1980*, Council on Environmental Quality (Washington: USGPO, 1981), pp. 148–152, based on the U.S. Environmental Protection Agency's air quality data bank, SAROAD (Storage and Retrieval of Aerometric Data).

A Standard Metropolitan Statistical Area (SMSA) is an area with an urban center of 50,000 persons or more, including the county containing that center and any neighboring counties that are closely associated with the central area by daily commuting ties. SMSAs contain not only urbanized areas, which occupy only 10% of the land, but also open space, forests, recreation areas, parks, and cropland.

The PSI values are an average of 23 SMSAs which were included because data were available. New York was excluded because comparable data for 1974 are not available in SAROAD. Other major SMSAs may have many days of unhealthful air, but comparable data for 1974–1978 are not available in SAROAD.

The PSI analysis for 1973–1978 is based on standards applicable during 1979, not on standards applicable at the time of monitoring. The primary standard for ozone was relaxed in 1979 from 160 to 240 micrograms per cubic meter per hour.

In addition to the five criteria pollutants, the product of total suspended particulates and sulfur dioxide is included. Other pollutants for which standards have been set can be readily added. Although lead is now a criteria pollutant, it has not yet been incorporated in the PSI.

12-4
Pollutant Standards Index in 24 Standard Metropolitan Statistical Areas, 1973–1978

1973: *Environmental quality—1978*, Council on Environmental Quality (Washington: USGPO, 1979), pp. 15–17, based on the U.S. Environmental Protection Agency's air quality data bank, SAROAD (Storage and Retrieval of Aerometric Data).

1974–1978: See 12-3.

In 1978 in these 24 SMSAs, photochemical oxidants were the primary pollutant in 15 SMSAs; carbon monoxide was the predominant pollutant in 6 SMSAs.

Total suspended particulates and sulfur dioxide caused high PSI readings in Chicago, Cincinnati, Salt Lake City, and other major industrial centers, but rarely do these readings exceed more than a few days per year.

12-5
National ambient carbon monoxide concentrations, 1972–1978

U.S. Environmental Protection Agency, Office of Air Quality and Standards, unpublished data.

CO, oxidants, SO_2, TSP, and NO_2 data are from the National Aerometric Data Bank (NADB).

Data collected at fixed monitoring sites are reported quarterly by local and State governments.

Annual composite averages of CO are based on daily 8-hour measurements taken at 183 urban monitoring sites. Sites selected are those with at least 5 years' data.

12-6
National ambient ozone concentrations, 1972–1977

National air quality, monitoring, and emissions trends report, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards (Washington: USGPO, 1978), EPA-450/2-78-052, fig. 3-6, p. 3-12.

Trends are based on the average of the 90th percentile of the hourly measurements taken from April through September.

Many sites are monitored only during this peak pollutant season when ozone values are highest. Of the 226 sites, 59 were in California.

12-7
National ambient sulfur dioxide concentrations, 1972–1977

See 12-6, fig. 3-5, p. 3-8.

Trends are based on the annual composite average of daily 24-hour averages. Data were collected at 1,233 monitoring sites.

12-8
National ambient total suspended particulate concentrations, 1972–1977

See 12-6, fig. 3-2, p. 3-2.

Trends are based on the annual composite average (geometric mean) of daily 24-hour averages.

Data were collected at 2,707 monitoring sites.

12-9
Ambient nitrogen dioxide concentrations, selected areas, 1972–1977

See 12-6, fig. 3-11, p. 3-18.

Sites were included if they had at least 3 years' data with at least 4,000 hourly observations per year.
Trends are based on annual composite averages of hourly measurements taken at 56 urban sites: *23 in California* (Los Angeles County, 9; Orange County, 2; Riverside, San Bernardino Counties, 6; San Francisco Bay area, 6) and *33 outside California* (Cleveland, 18; Louisville, 9; Atlanta, 6).

12-10
Ambient trace metal concentrations in 92 urban areas, 1965–1974

National trends in trace metals in ambient air, 1965–1974, U.S. Environmental Protection Agency (Washington: USGPO, 1977), pp. 8, 9.

Data were taken from the National Air Surveillance Network (NASN).
Trends are based on the annual average of the 50th percentile median from 92 urban high-volume stations in 92 center-city and suburban business areas.
Except for lead, there are no ambient standards proposed nor is there consensus as to what concentrations may be harmful to human health.
Recent data for vanadium and cadmium cannot be detected in smaller concentrations.

12-11
Acid precipitation in the eastern United States, 1955–1976

Based on "Acid rain," Gene E. Likens, Richard R. Wright, James N. Galloway, and Thomas J. Butler, *Scientific American* 241(4): 43-51 (1979), copyright 1979 by Scientific American, Inc., all rights reserved.

12-12 to 12-19
General note on emissions

Data are compiled from the U.S. Environmental Protection Agency's National Emissions Data Bank (NEDB), other EPA data sources, and other published sources.
States are required to report semi-annually.
Data are not limited to major metropolitan areas but include point and areal sources.
Transportation includes highway vehicles, aircraft, railroads, vessels, and miscellaneous mobile engines such as farm equipment, industrial and construction machinery, lawnmowers, and snowmobiles.
Stationary includes all fuel combustion in boilers, stationary internal combustion engines, and other stationary combustion equipment. Emissions are from electric power plants, industry, and residential, commercial, government, and educational fuel consumers.
Industrial includes manufacturing equipment.

12-12
Carbon monoxide emissions, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Other includes emissions from stationary fuel combustion, solid wastes, forest fires, and managed burnings.

12-13
Hydrocarbon emissions, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Other includes emissions from stationary fuel combustion, solid waste, and use of organic solvents.
Hydrocarbons may be referred to as volatile organic compounds although they are not strictly comparable. Hydrocarbons include photochemically nonreactive compounds (for example, methane); volatile organic compounds do not.

12-14
Nitrogen oxide emissions, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Stationary fuel combustion includes emissions from electric utilities, industrial establishments, and residential, commercial, and institutional sources.
Other includes emissions from industrial processes and solid wastes.
Due to methodology, emission estimates include all nitrogen oxides. Ambient measurements include only nitrogen dioxide.

12-15
Nitrogen oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977

U.S. Environmental Protection Agency, Office of Air and Waste Management, unpublished data.

Data exclude a small amount (about 0.4 million metric tons per year) of nitrogen oxide emitted by stationary fuel combustion sources that use kerosene, liquified petroleum gas, and other fuels.

12-16
Sulfur oxide emissions, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Stationary fuel combustion includes emissions from electric utilities and industrial, residential, commercial and institutional sources.
Other includes emissions from solid wastes and transportation.
Due to methodology, emission estimates include all sulfur oxides. Ambient measurements include only sulfur dioxides.

12-17
Sulfur oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Data exclude a small amount (0.15 million metric tons per year) of sulfur oxide produced by industrial stationary fuel combustion sources that use other fuels.
Natural gas does not produce sulfur oxide when burned.

12-18
Total suspended particulate emissions, 1970–1977

See 12-6, pp. 5-5 to 5-12.

Other includes emissions from solid wastes and transportation.
Data include both suspended and settled particulates, in contrast to ambient TSP measurements, which include only suspended particulates.

12-19
Total suspended particulate emissions from industrial sources, 1970–1977

See 12-6, pp. 5-5 to 5-12.

12-20
Compliance status of major stationary air pollution sources, 1975–1979

U.S. Environmental Protection Agency, Office of Enforcement, unpublished data for the Compliance Data System, which includes probable compliance data collected on a quarterly basis from State and local air pollution control agencies.

Approximately 200,000 stationary sources are subject to State Implementation Plans, which set limits on emissions as part of a statewide plan to reduce ambient concentrations of criteria pollutants. Of these sources, 23,760 are classified as major (or Class A) sources because each of them is capable of emitting more than 100 tons of pollutant each year.
Minor (or Class B) sources are all other facilities (approximately 176,000).

12-21
Compliance status of major stationary air pollution sources, by industry, 1979

The 13 major categories shown here include 5,412 sources—about a fifth of all major stationary sources.

Chapter 13

Biosphere

All life on earth exists in the biosphere, the thin layer of air, land, and water that covers the earth and is energized by the sun. Within the biosphere live some 3 to 10 million species of plants and animals. In size, they range from the great blue whale *(Balaenoptera musculus)* and giant sequoia *(Sequoiadendron giganteum)* to the smallest single-cell organism. Among them are human beings *(homo sapiens)*, with a population of more than 4 billion.

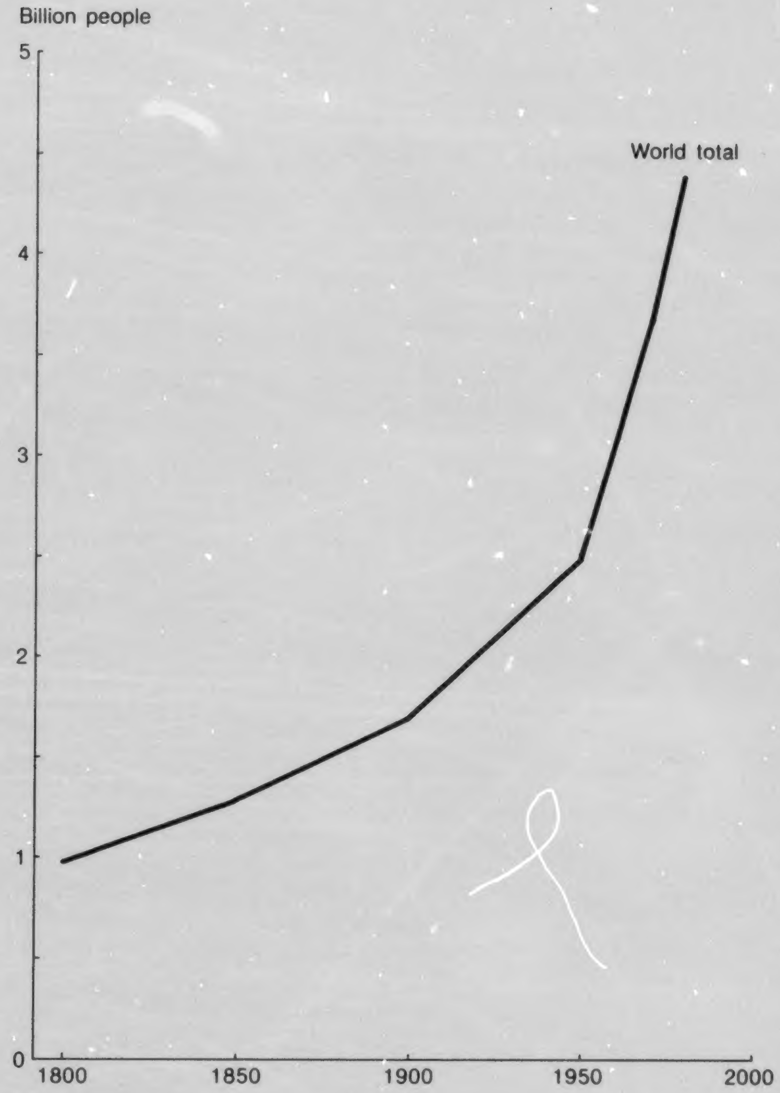
The biosphere's life support systems are being taxed by ever greater numbers of people, by an accelerating demand for resources—fueled by the needs of modern agriculture, industry, and transportation, and by expanding human settlements. Some of the stresses are obvious—degraded cropland, deforestation, desertification, loss of wildlife, and pollution poisoning. The effects of others may not be known until the damage is done.

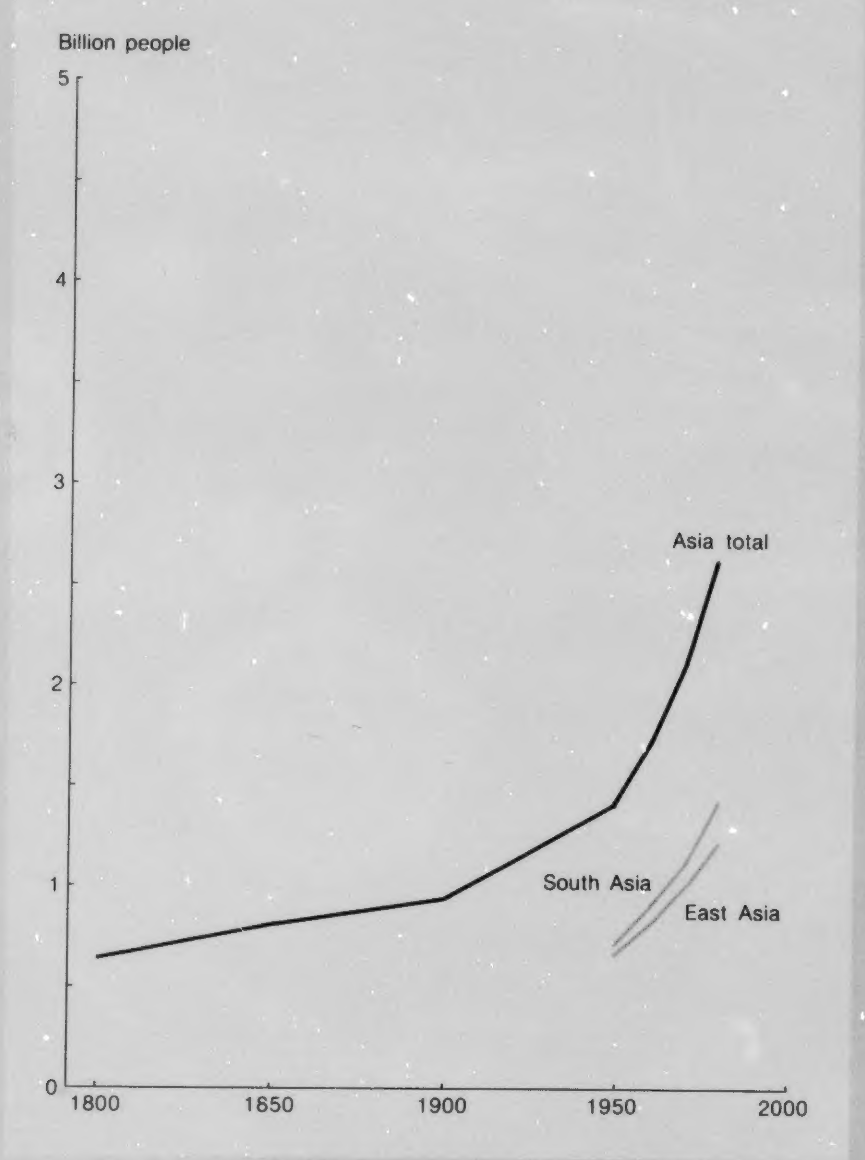
Population

In 7000 B.C., the earth was populated by some 5 to 10 million people. By 1 A.D., the number had grown to between 200 and 400 million—about the combined number now living in the United States and Japan. Slow, unsteady growth continued until the late 18th century when world population probably stood at less than 1 billion. With the advent of the industrial revolution, the pattern changed to a steady increase. World population is now more than 4.4 billion. The time it takes for world population to double dropped from 173 years in 1800 to 41 years in 1979.

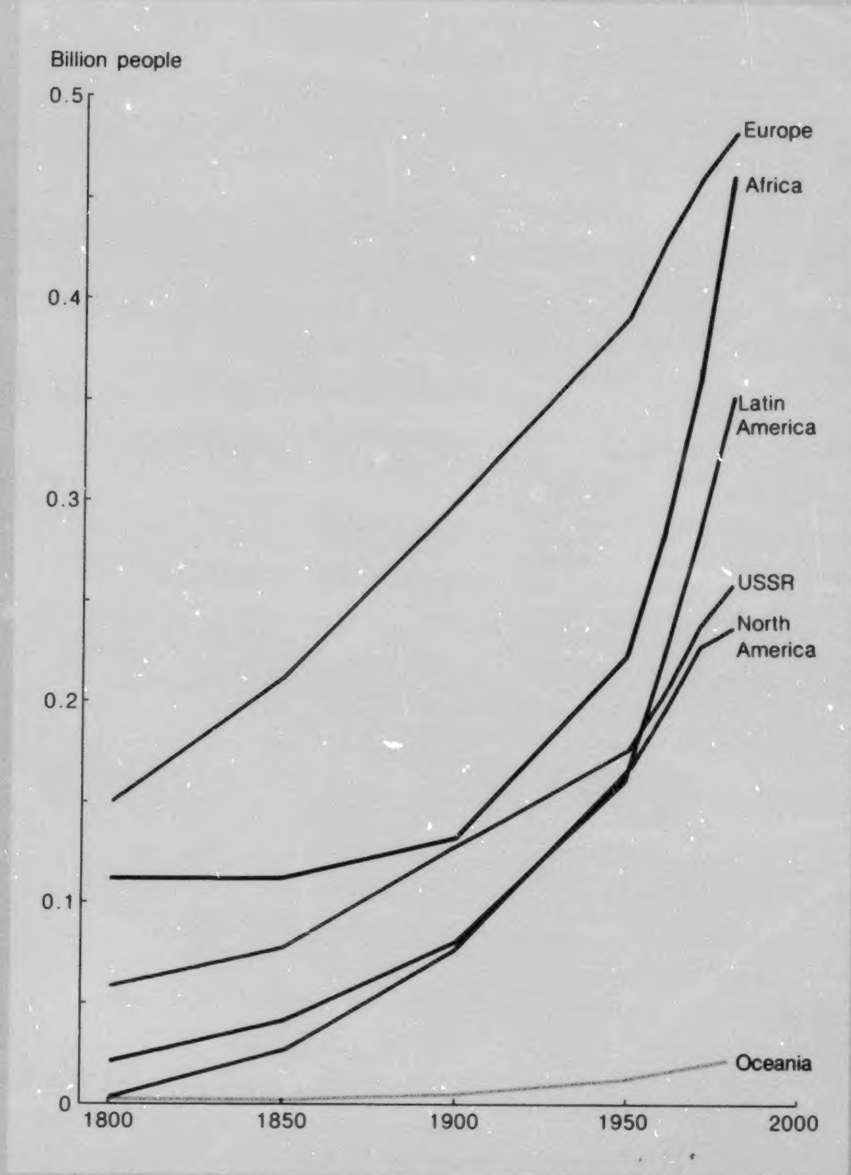
13-1
World population, by region, 1800-1979

For at least 200 years, Asia has been home for about 60% of the world's population. Today, roughly 2.6 billion people live there.




Billion people
5
4
3
2
1
0
1800
1850
1900
1950
2000
Asia total
South Asia
East Asia

502


Billion people
0.5
0.4
0.3
0.2
0.1
0
1800
1850
1900
1950
2000
Europe
Africa
Latin America
USSR
North America
Oceania

503

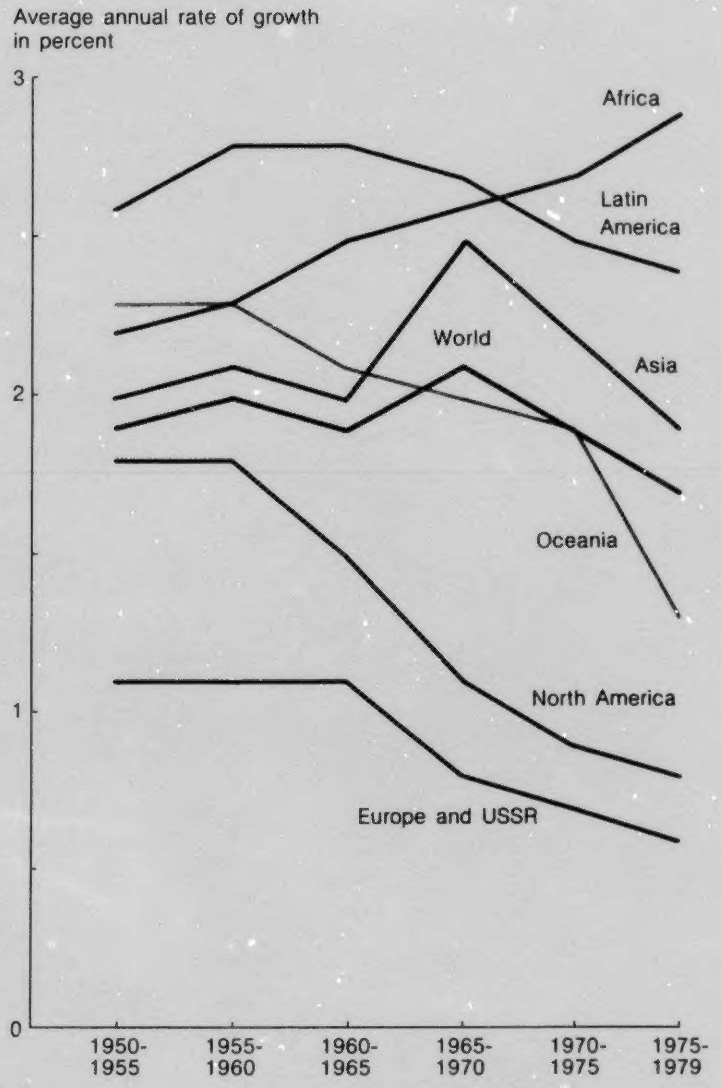
13-2

World population growth rates, by region, 1950–1979

During the 1960s, the average rate of world population growth was 2% per year, the highest rate in recent centuries. In the 1970s, the rate declined, reaching 1.8% in 1979.

Growth rates are highest in much of the developing world due to high levels of fertility and marked reductions in mortality immediately following World War II. Improved living conditions—such as sanitary drinking water, more food, and better health services—have greatly reduced infant mortality, allowing many more young people to reach maturity and have families of their own.

Declines in the rate of growth in North America, Europe, the USSR, and Oceania are due mainly to reduced fertility. People there are choosing to have smaller families. In Belgium, the German Democratic Republic, and the United Kingdom, for example, growth rates are close to zero. The Federal Republic of Germany and Austria have negative growth rates.

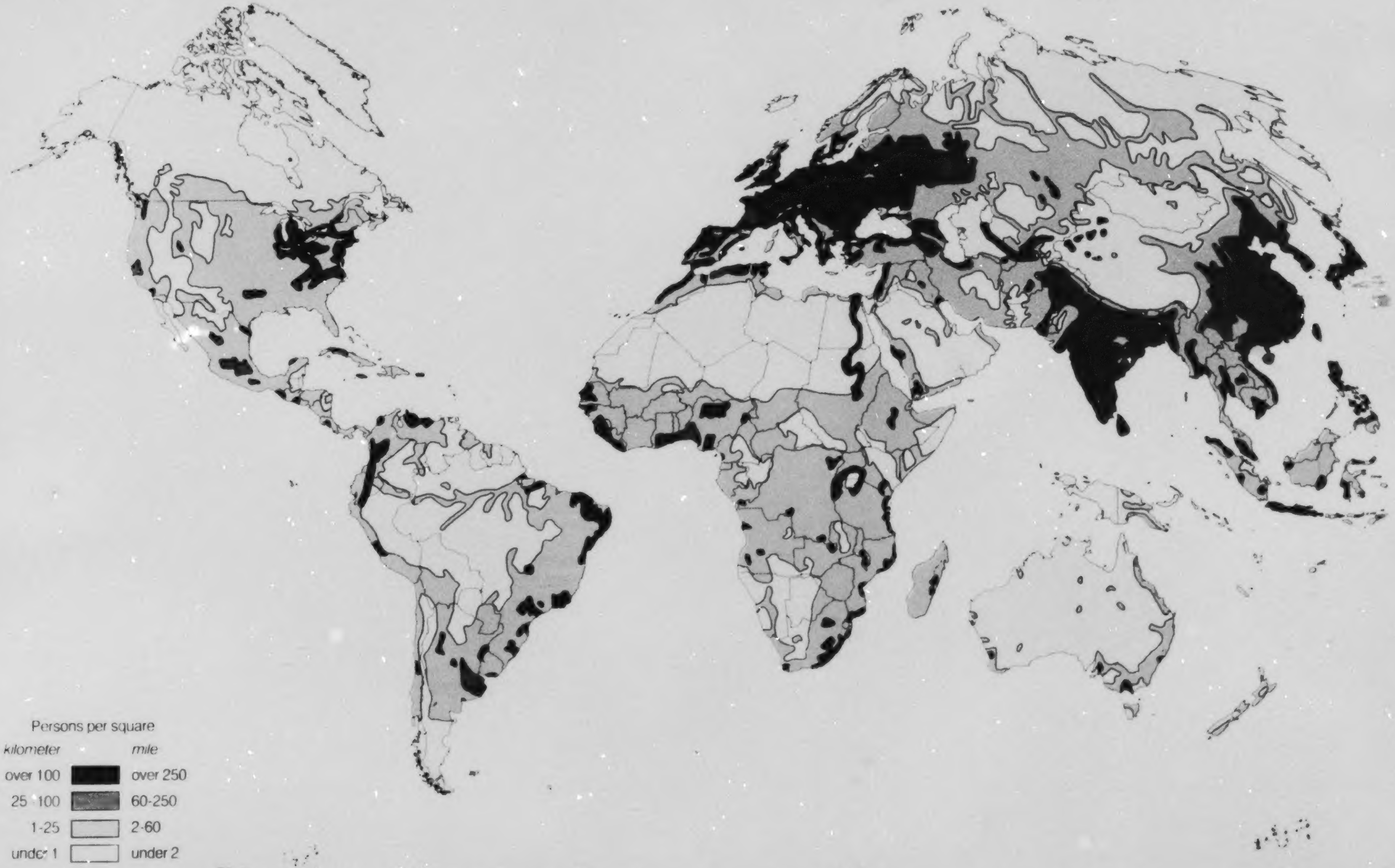


13-3

Population density, 1975

The earth as a whole averages 75 people per square mile. The United States is somewhat less densely populated (60 people per square mile). The density is higher in less developed regions (101 per square mile) than in more developed regions (48 per square mile).

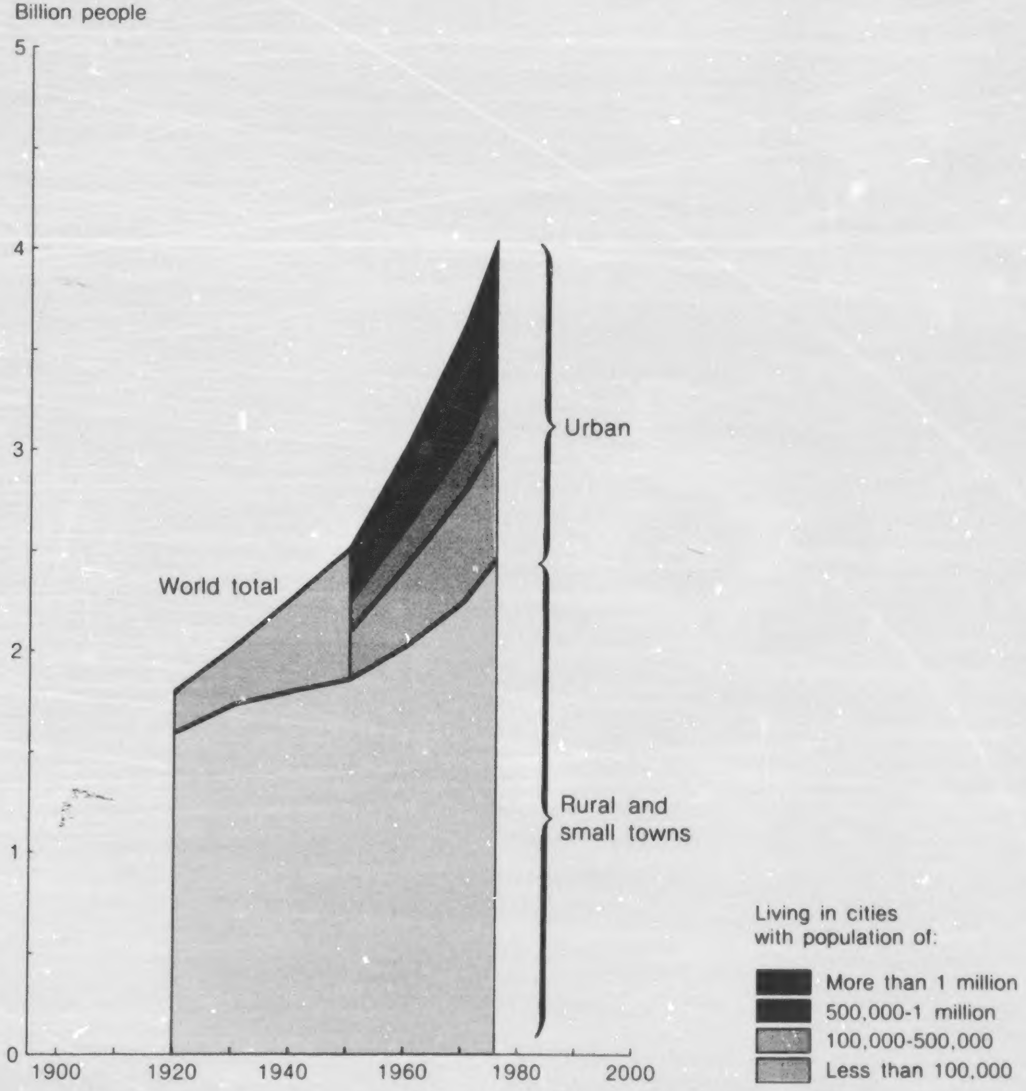
Densities are usually much higher in agriculturally productive lands such as the Mississippi, Indus, and Po river valleys and along coastlines. Some of the highest densities are in the island nations of Singapore, Hong Kong, Great Britain, Japan, and the Caribbean.


Persons per square
kilometer
mile
over 100 ■ over 250
25-100 ▨ 60-250
1-25 ▢ 2-60
under 1 ☐ under 2

13-4

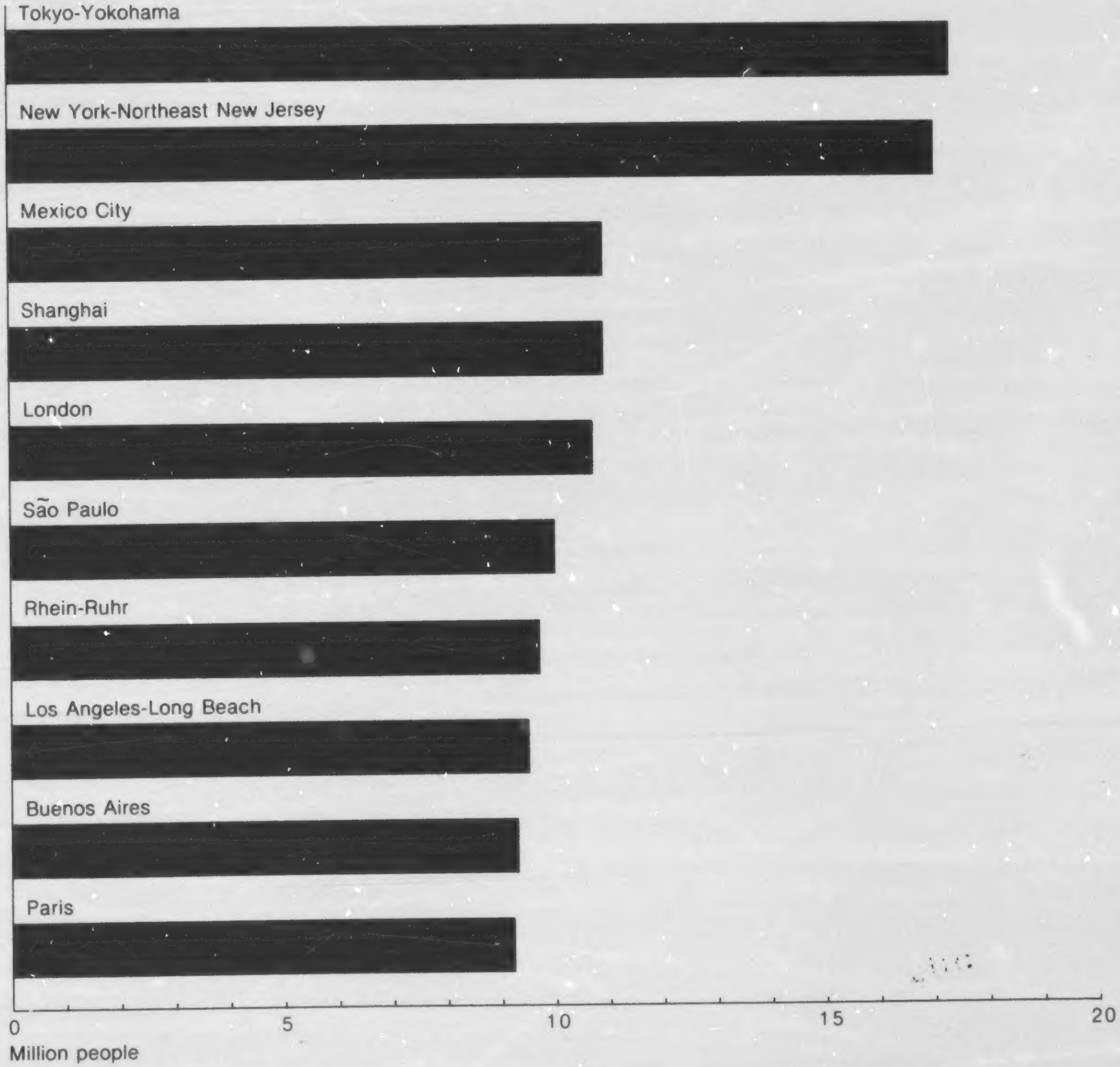
Population in urban and rural areas, by size of area, 1920–1975

The urban population—the number of people living in settlements of 20,000 or more—doubled between 1950 and 1975. In 1950, the urban share of world population was 28%. By 1975, it had risen to 40%.



13-5
Ten largest cities in the world, 1975

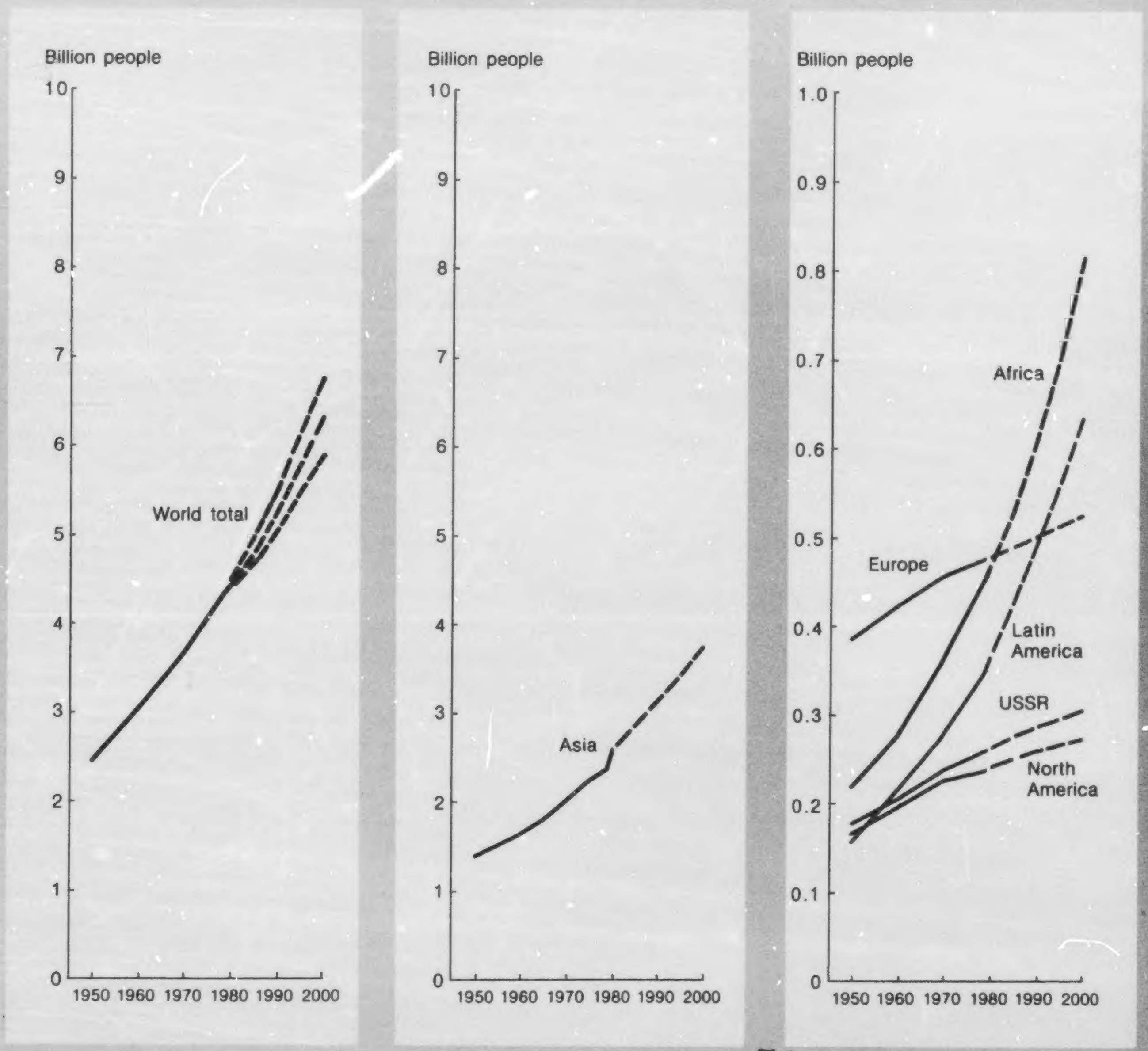
An important trend is the proliferation of cities of more than 1 million people. In 1900, there were 11; in 1950, 71; and in 1975, 181. The 10 largest cities (including their major suburbs) are Tokyo-Yokohama, New York-Northeast New Jersey, Mexico City, Shanghai, London, São Paulo, Rhein-Ruhr, Los Angeles-Long Beach, Buenos Aires, and Paris.



13-6
Population by region, 1950–1979, with projections to 2000

World population is projected to reach between 5.9 and 6.8 billion by the year 2000. Using the mid-level projection, it is expected to increase by 1.9 billion, or 44%, in the 21 years from 1979 to 2000.

Most of the increase is expected to occur in developing countries. Africa and Latin America are projected to double in population. Asia will continue to have the largest number of people.



13-1
World population, by region, 1800–1979

1800–1900: *The determinants and consequences of population trends,* United Nations (New York, 1973), v. 1, p. 21.

1950–1979: *World population 1979: Recent demographic estimates for the countries and regions of the world,* U.S. Bureau of the Census (Washington: USGPO, 1980), tables 2, B-2, D-1, pp. 24, 168, 376.

U.S. Bureau of the Census, unpublished data.

13-2
World population growth rates, by region, 1950–1979

World population 1979: Recent demographic estimates for the countries and regions of the world, U.S. Bureau of the Census (Washington: USGPO, 1980), table 2, p. 24.

13-3
Population density, 1975

The global 2000 report to the President, Council on Environmental Quality and U.S. Department of State (Washington: USGPO, 1980), v. 2, the technical report.

13-4
Population in urban and rural areas, by size of area, 1920–1975

Demographic yearbook 1960, United Nations (New York, 1960), table 2, p. 116.

The determinants and consequences of population trends, United Nations (New York, 1973), v. 1, pp. 190, 578.

Trends and prospects in the population of urban agglomerations, 1950–2000, as assessed in 1973–1975, United Nations (New York, 1975), pp. 13, 21.

World urbanization 1950–1970, Kingsley Davis (Berkeley: University of Calif., 1969), v. 1, tables A, B, pp. 57–111.

Rural data for 1920–1940 are not strictly comparable to that for 1950–1975.

13-5
Ten largest cities in the world, 1975

Trends and prospects in the population of urban agglomerations, 1950–2000, as assessed in 1973–1975, United Nations (New York, 1975), p. 61.

13-6
Population by region, 1950–1979, with projections to 2000

1950–1979, except Asia: See 13-1.

1980–2000, and Asia, 1950–1979: *Illustrative projections of world populations to the 21st century,* U.S. Bureau of the Census (Washington: USGPO, 1979), current population reports, special studies series P-23, n. 79, pp. 17–18.

U.S. Bureau of the Census, unpublished data.

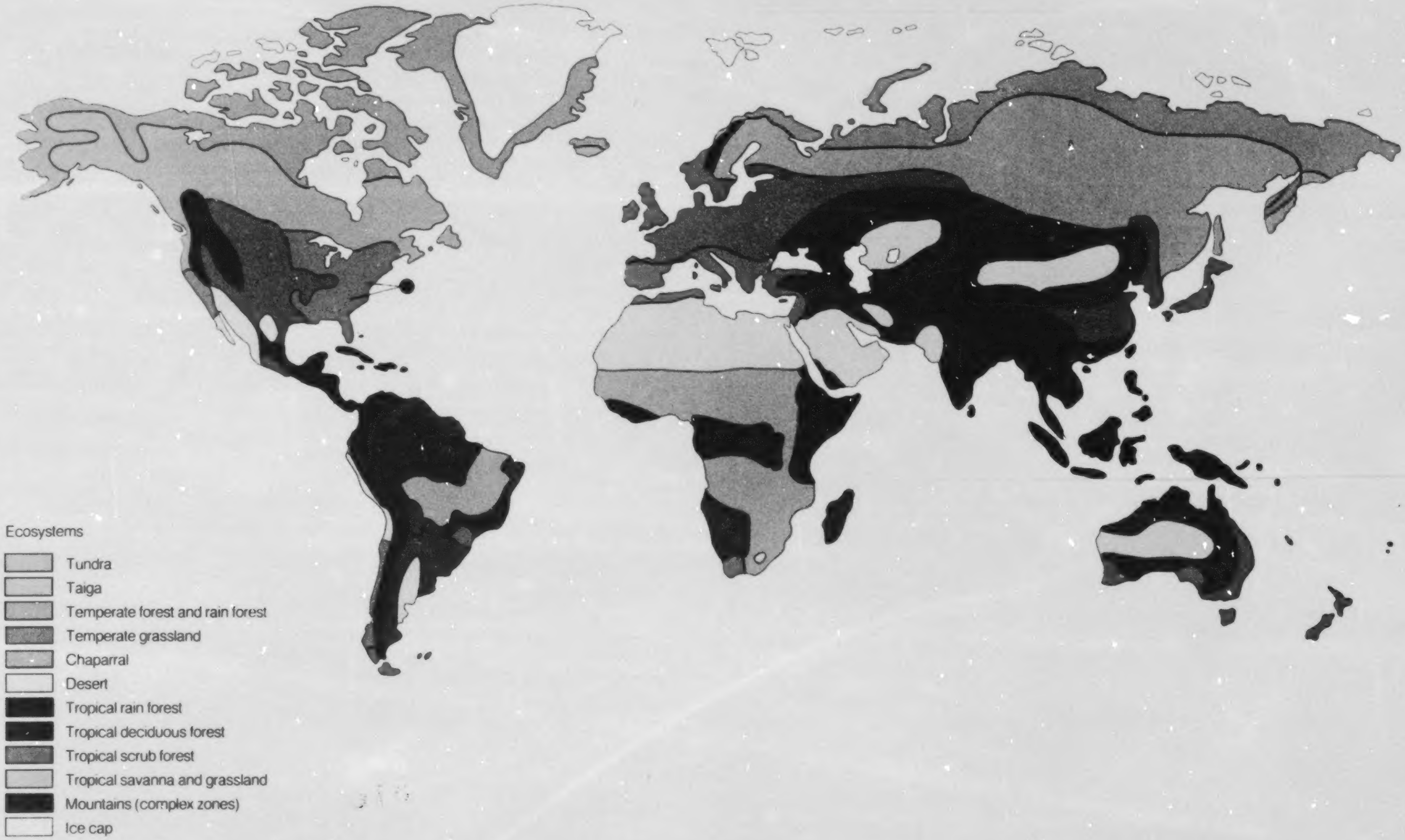
Asia includes Oceania.

Land

The earth's surface encompasses 149 million square kilometers of land and 361 million square kilometers of marine waters. Only a small portion of the land and an even smaller portion of the ocean are highly productive biologically. These are the areas that support most of the growth of green plants and thus provide food energy for life on earth.

13-7
Major ecosystems of the world, 1970s

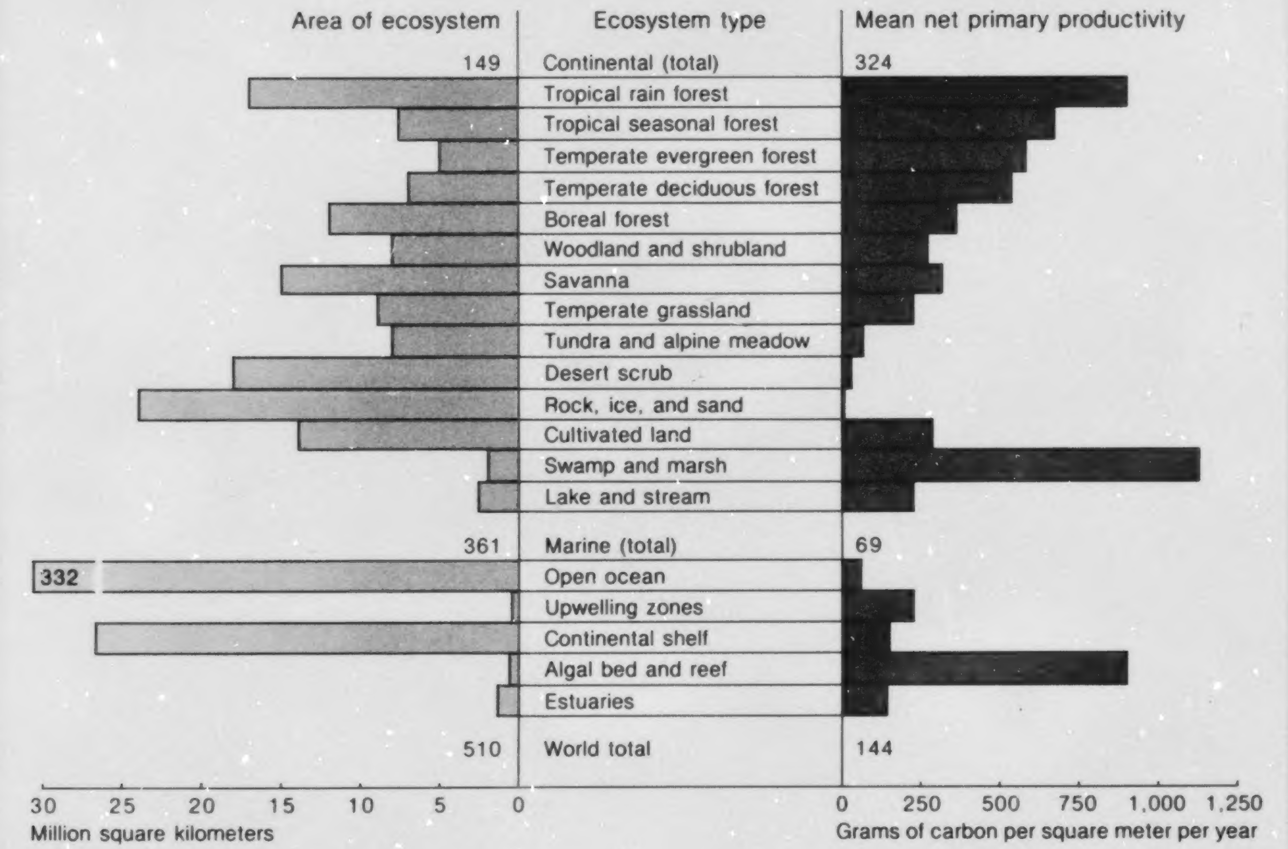
The land surface of the earth can be classified into 12 major ecosystems. The classification of an ecosystem is determined by its dominant plants and animals, whose presence is largely influenced by temperature, precipitation, and sunlight. The world's major ecosystems include tundra, tiaga, temperate forest, temperate grassland, tropical deciduous forest, tropical rain forest, desert, and others.


Ecosystems
Tundra
Taiga
Temperate forest and rain forest
Temperate grassland
Chaparral
Desert
Tropical rain forest
Tropical deciduous forest
Tropical scrub forest
Tropical savanna and grassland
Mountains (complex zones)
Ice cap

517

518

13-8
Area and productivity of ecosystems, 1970s



The most extensive territorial ecosystems are desert, rock, and ice; tropical rain forest; desert scrub; savanna; and cultivated land.

The most productive systems in terms of primary biological productivity, are swampland, marshland, and tropical rain forests. Primary productivity is that part of total production contributed by green plants in a given year. It is measured in grams of carbon produced per square meter per year.

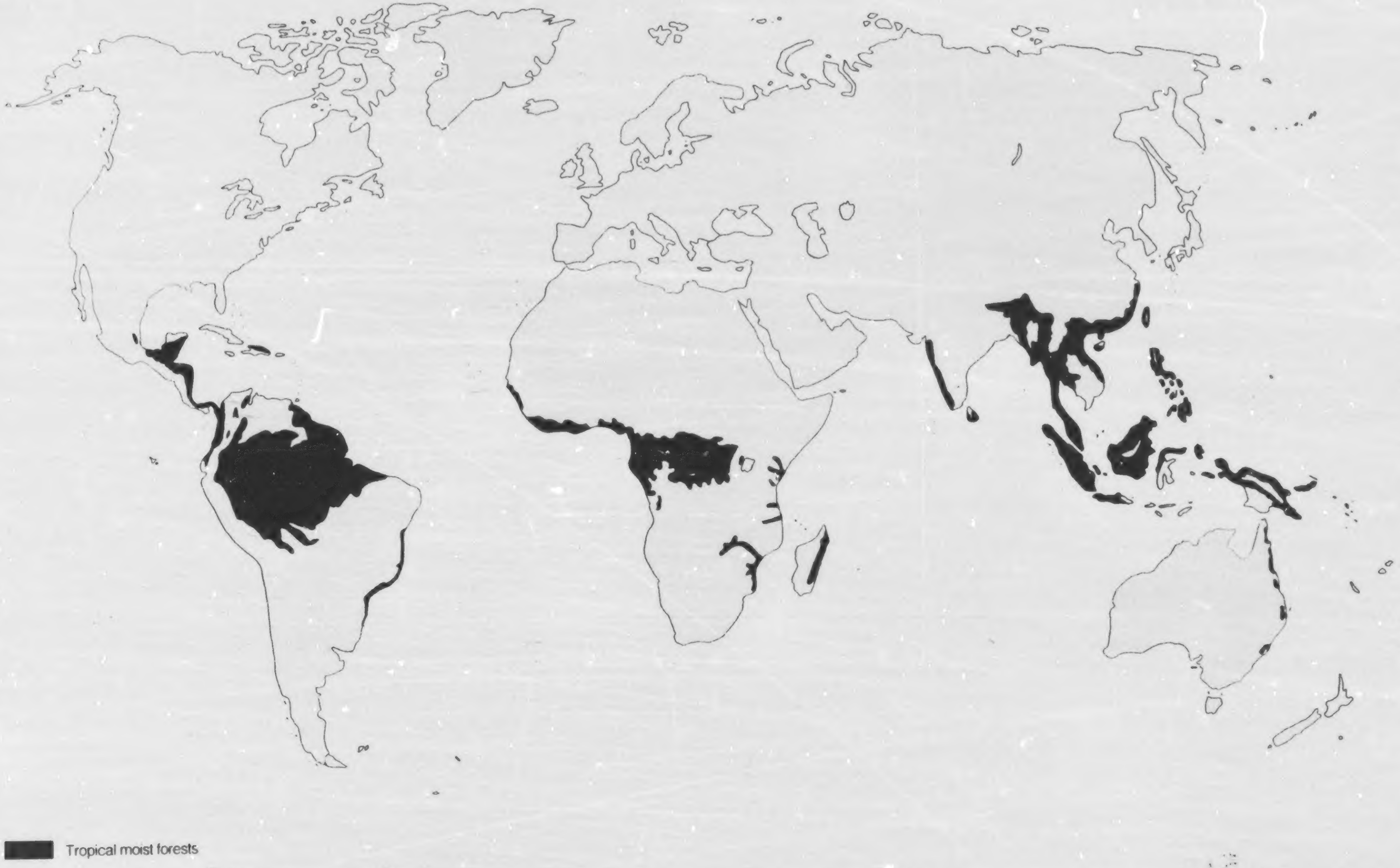
The seas cover nearly three quarters of the globe, but marine plants account for only a third of the biosphere's primary production, about 24.9 billion metric tons out of a global total of 73.2 billion. Only relatively small areas of the ocean are very productive; these areas include estuaries, algal and seagrass beds, and reefs.

13-9
Tropical moist forests, 1970s

Three major ecosystems are under especially intense pressure: tropical moist forests; arid and semiarid land; and cropland.

For centuries, tropical moist forests resisted intensive human exploitation. Today, with rapid growth in population and in the demand for living space, food, and materials, the tropical moist forests of Central and South America, West Africa, and Southeast Asia are changing. Millions of acres are now being cleared each year for farming and cattle ranches, cut for firewood, or logged for valuable hardwood. Closed tropical forests are decreasing by 10–20 million hectares (1%–2%) per year. In addition to these losses, the quality of large areas of the remaining forests is being degraded.

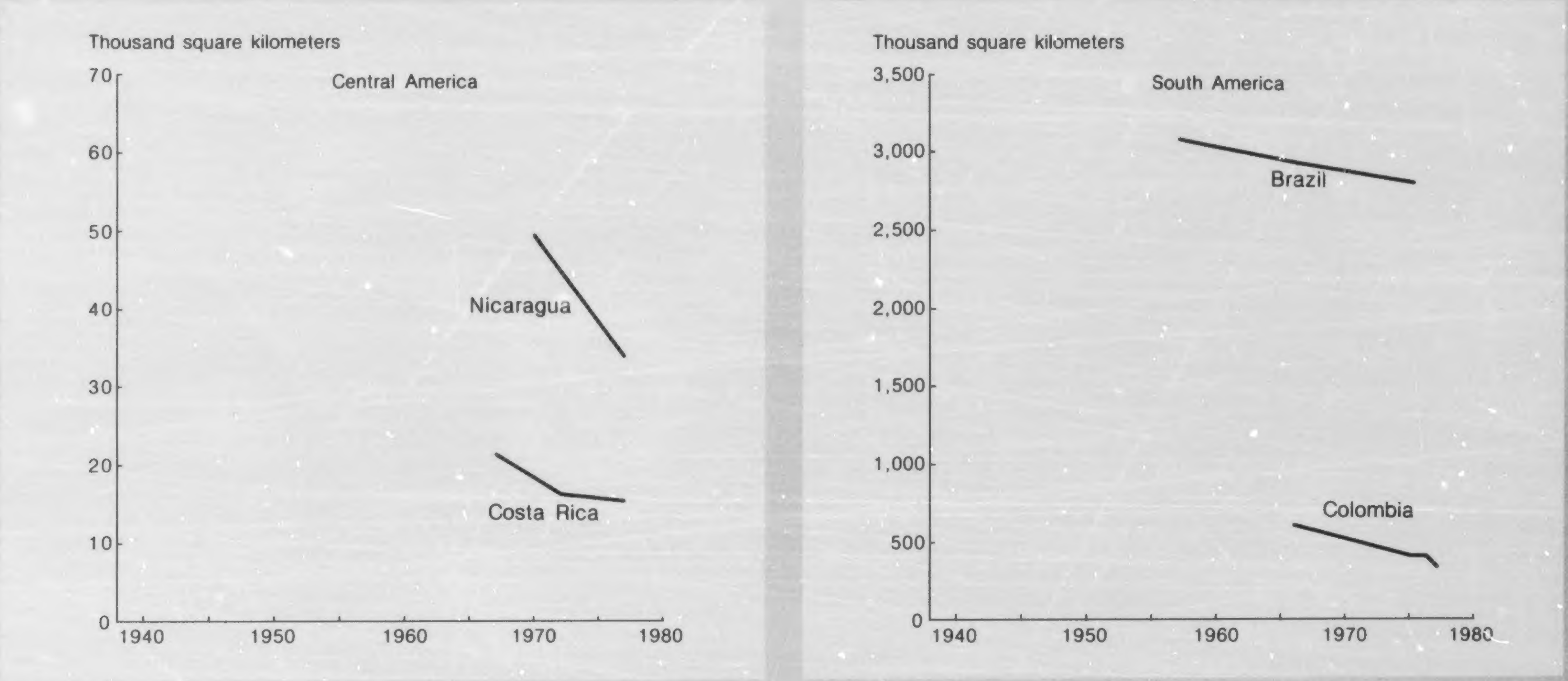
Rapid loss of tropical forest cover can have severe consequences for society and the environment: Economically accessible forests become limited. People, particularly the poorest, are without wood for fuel, shelter, fiber, or must spend much more time searching for suitable materials. Watersheds become denuded. Flooding increases in frequency and severity. Ground water is depleted. Increased erosion reduced topsoil. Reservoirs and irrigation ditches are silted, reduces agriculture and hydropower. Wildlife is reduced in abundance and in diversity, with many species threatened with extinction.


■ Tropical moist forests

521

522

13-10
Tropical moist forests, by region and country, 1945–1978



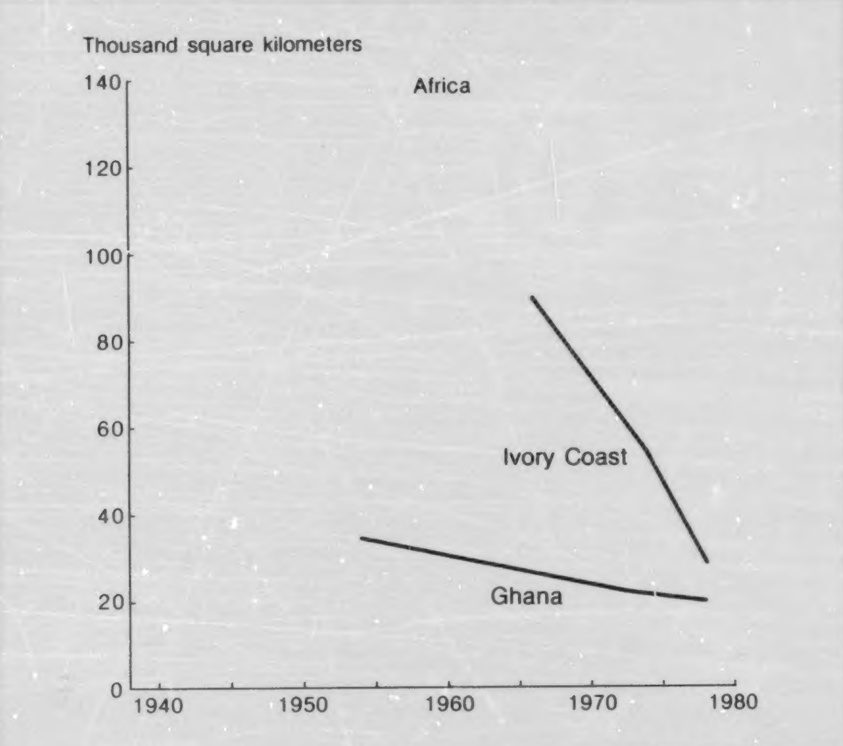
Large-scale conversion of rain forest is taking place in all of the world's tropical regions.

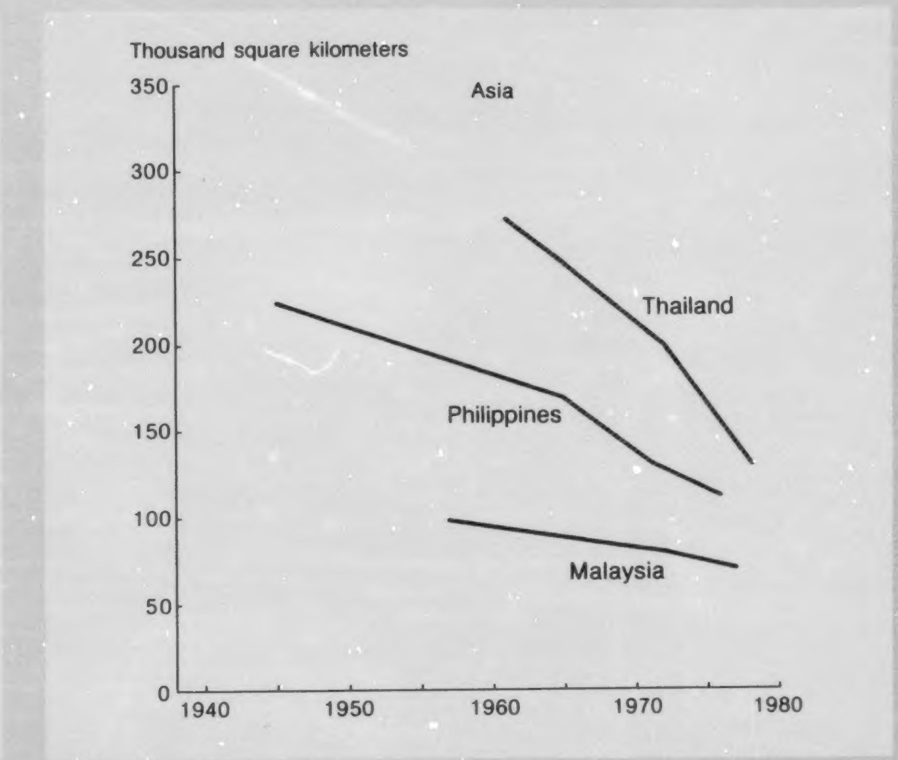
Tropical moist forests in Nicaragua have declined in the past decade by 30% as a result of timber exploitation, shifting cultivation, and growth in agricultural settlements. The government is now encouraging planned agriculture to reduce pressure on the remaining primary forest.

Twenty-five percent of Costa Rica's forests have been lost in the past decade. The Natural Resources Institute was established to evaluate forest ecosystems and integrate land use planning. National parks are being expanded to protect much of the remaining forest.

Brazil alone contains more than a third of the world's tropical moist forests—about 3 million square kilometers. The amount of forest converted to agricultural use and cattle raising has been substantial. National parks are being established and conservation programs developed to reduce conversion of some unique areas.

Closed forests in Colombia have declined by about 40% since the mid-1960s.





About 20% of the Ivory Coast's tropical forest remains. Almost all forest areas outside reserves have been logged and farmed.

Most of Ghana's moist forests have been severely depleted; the ones remaining are confined to forest reserves.

Thailand's forests have been reduced to a fourth of their original size. An extensive program of reforestation and conservation is underway to increase tropical moist forests to 40% of Thailand's land area. Nine national parks and wildlife refuges have been established, but deforestation continues even in the parks because people are desperate for cropland and fuelwood.

In 1965, 57% of land in the Philippines was forested. By 1976, only 38% was. Losses of some 5,000 square kilometers per year are being recorded. Plans have been made to increase forest acreage through reforestation to 42% of the country's total area by the year 2000.

Malaysia has the most intensively managed forest economy of any tropical country. Logging and wood processing are major industries. Roughly 55% of the Malaysian peninsula is still forested, and half of that is undisturbed. Nevertheless, Malaysian forests are being depleted at a rate of almost 4,000 square kilometers per year.

13-11

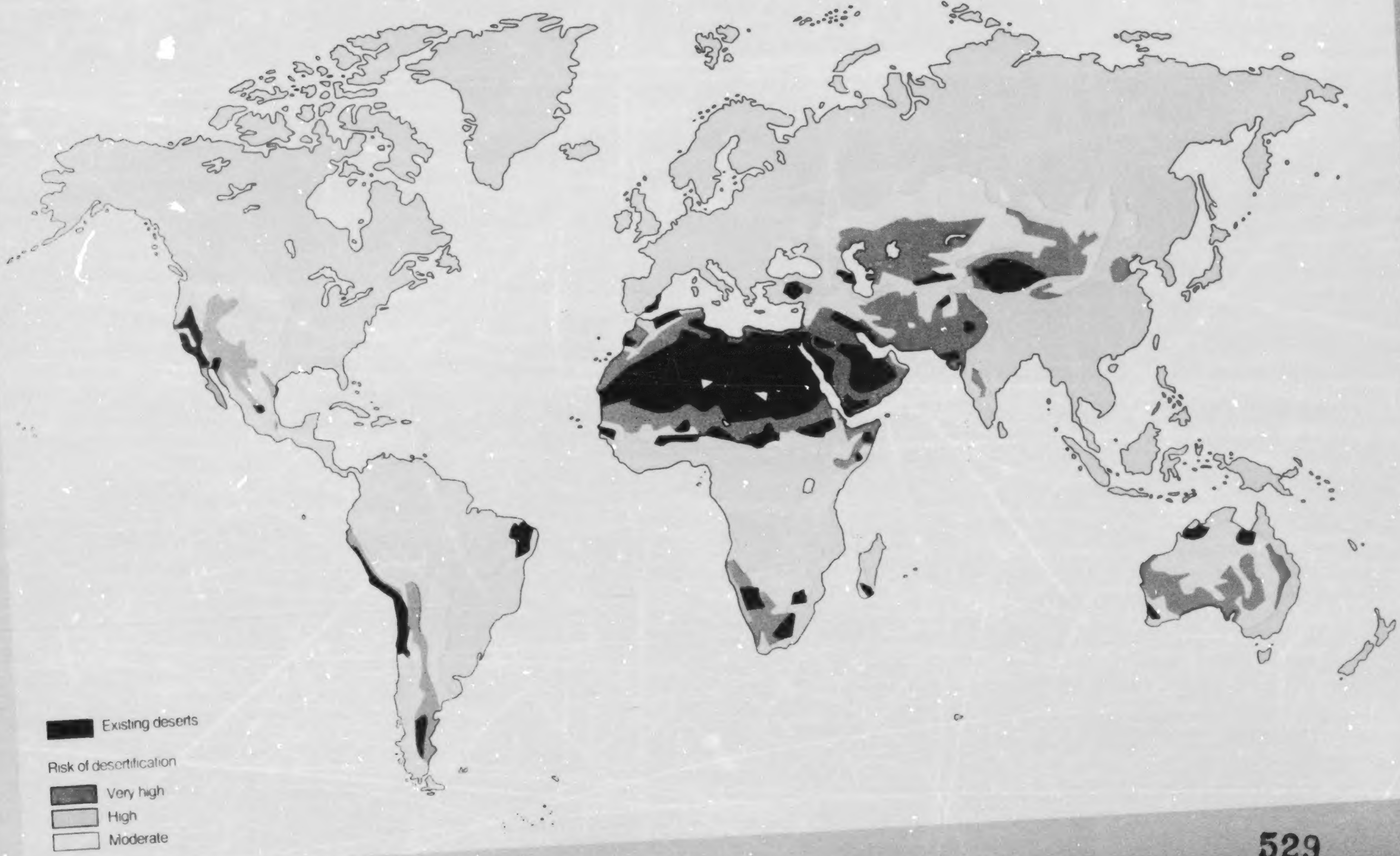
Lands vulnerable to desertification, 1970s

Desertification of lands worldwide is increasing at an estimated rate of 50,000 square kilometers per year. In the past 50 years in Africa alone, 650,000 square kilometers of land bordering the Sahara that were once suitable for agriculture and grazing have become barren desert.

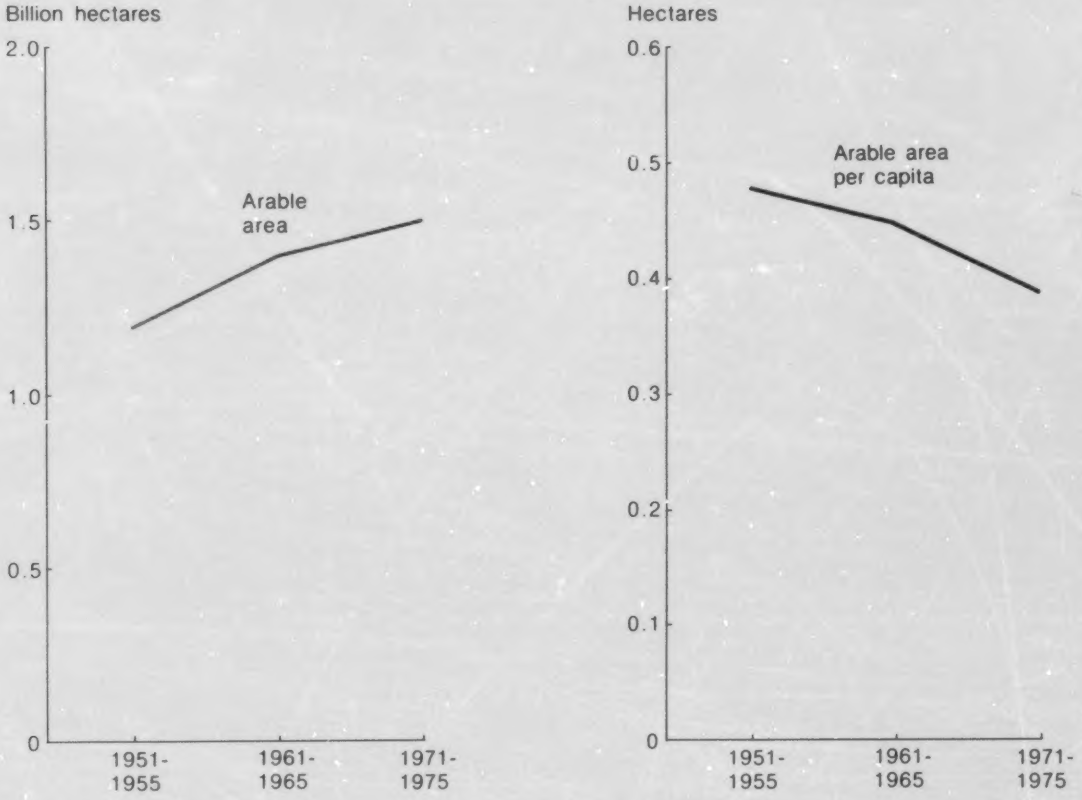
Desertification occurs where vegetation is fragile, subject to extremes in wind, temperature, or rainfall, or highly vulnerable to poor management or natural disaster. Direct causes of desertification are overgrazing, poor cropping practices, wood cutting, uprooting of shrubs, inappropriate recreational uses, and excessive burning of grasslands and forests. Such activity may cause progressive degradation, possibly to a point where damage is practically irreversible.

Among the earth's arid and semiarid lands, 13% are already desert. Of the remaining 87%, the risk of becoming desert is very high in 7%, high in 34%, and moderate in 36%. Risk is slight on about 10% of the land.

At this time, desertification could be reversed in many areas by eliminating activities that degrade the land and by rehabilitating seriously damaged areas.


Existing deserts
Risk of desertification
Very high
High
Moderate

13-12
World arable land, 1951-1975



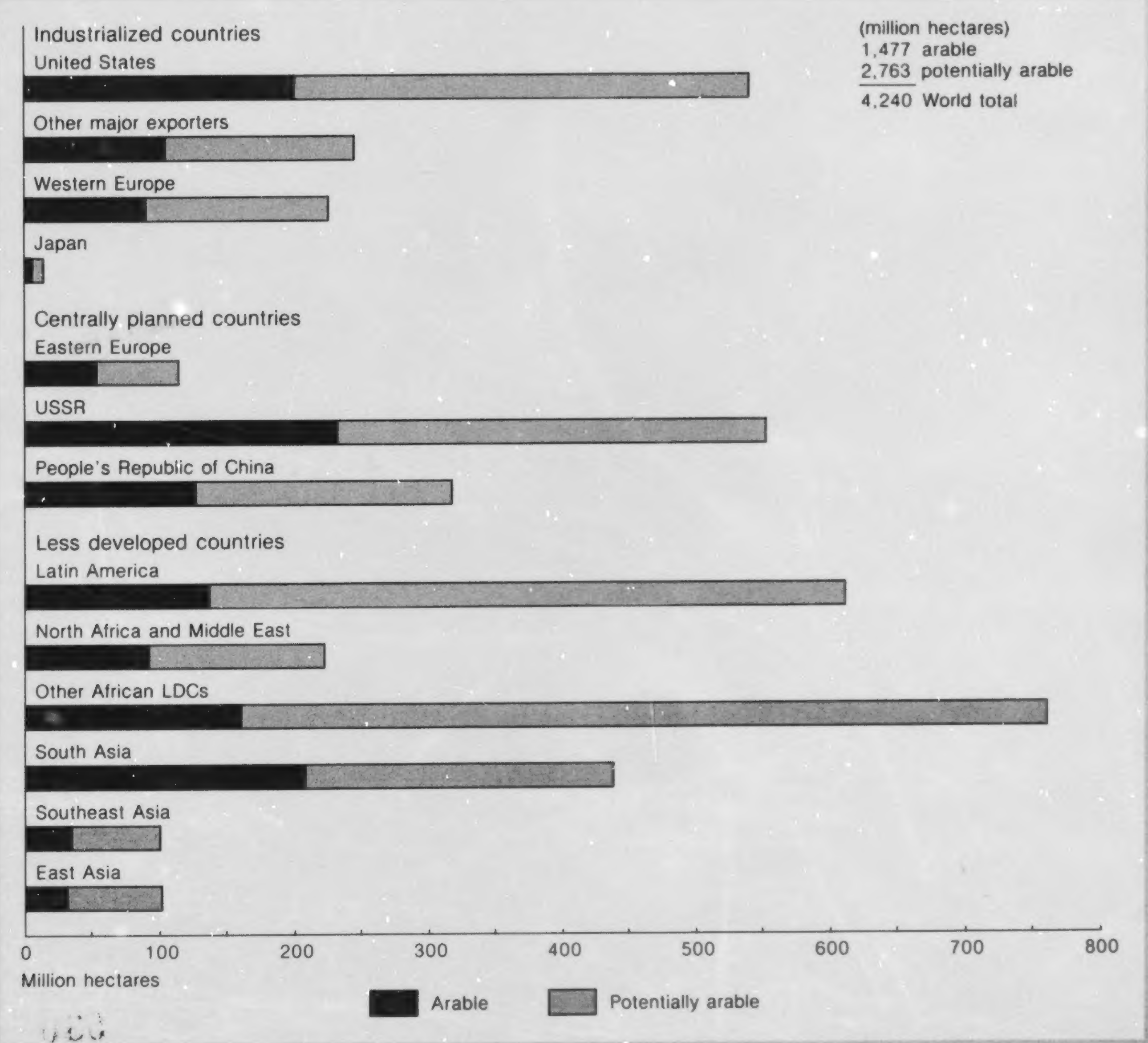
The amount of land used for crops worldwide is increasing but at slower rates than before. Millions of hectares are brought under cultivation for the first time each year, but almost as much is taken out of cultivation to be urbanized, returned to pasture or forest, or abandoned.

With world population growing rapidly and increases in total arable land minimal, arable land per capita is declining.

13-13
Arable and potentially arable land, by region, 1970s

The largest areas of arable land are in Asia, North America, and the USSR.

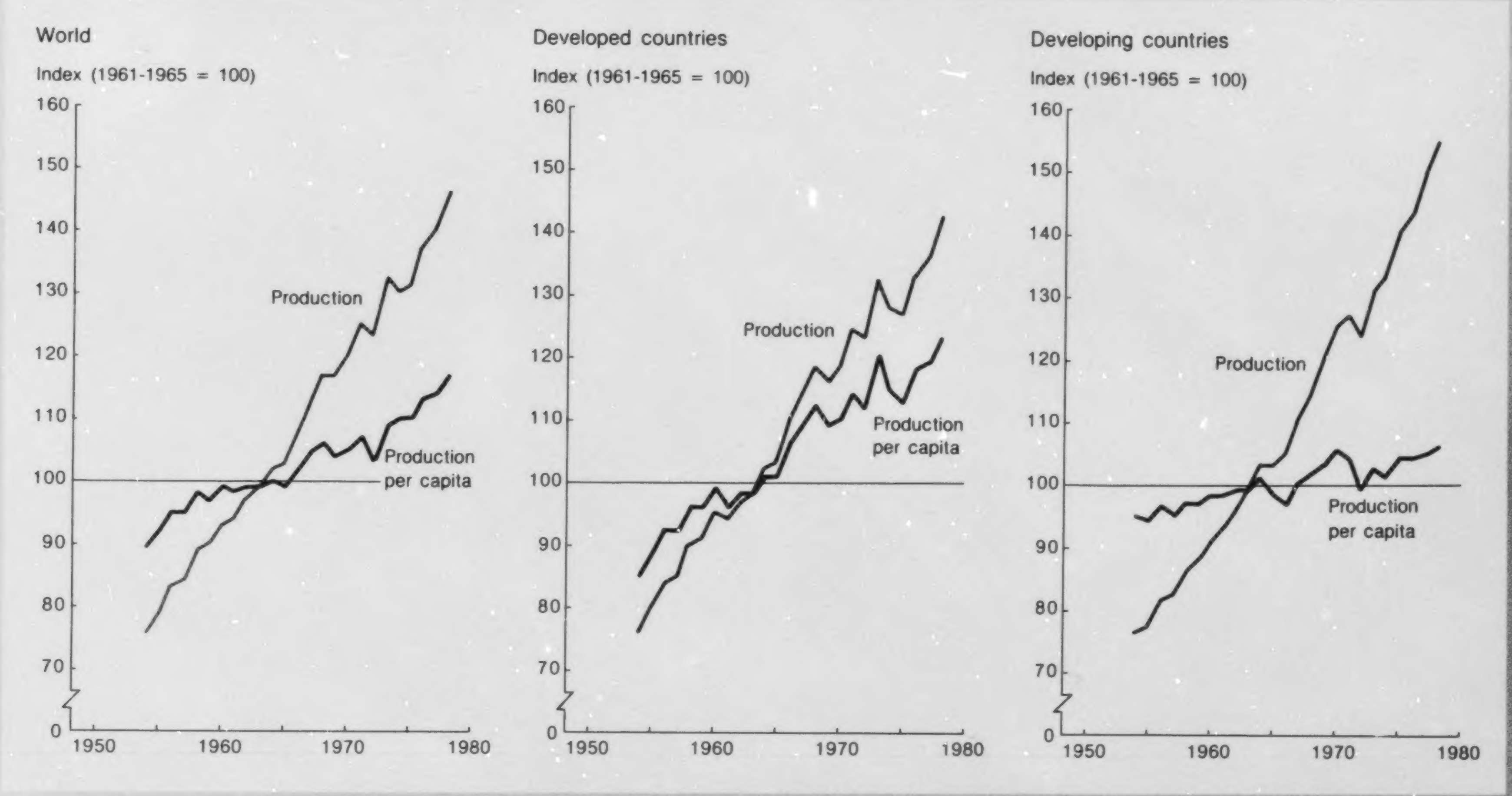
Nearly all countries have the potential to expand cultivated areas. The largest reserve of potentially arable lands are in Africa and South America, but many of these lands are poorly suited to agricultural production and face one or more environmental constraints. They contain infertile soils, are remote or isolated from population centers, lack adequate or properly timed rainfall, are subject to erosion, have a short growing season, do not have access to needed irrigation, or have a combination of these and other characteristics. In short, it appears that the best and most accessible lands are already in use.



531

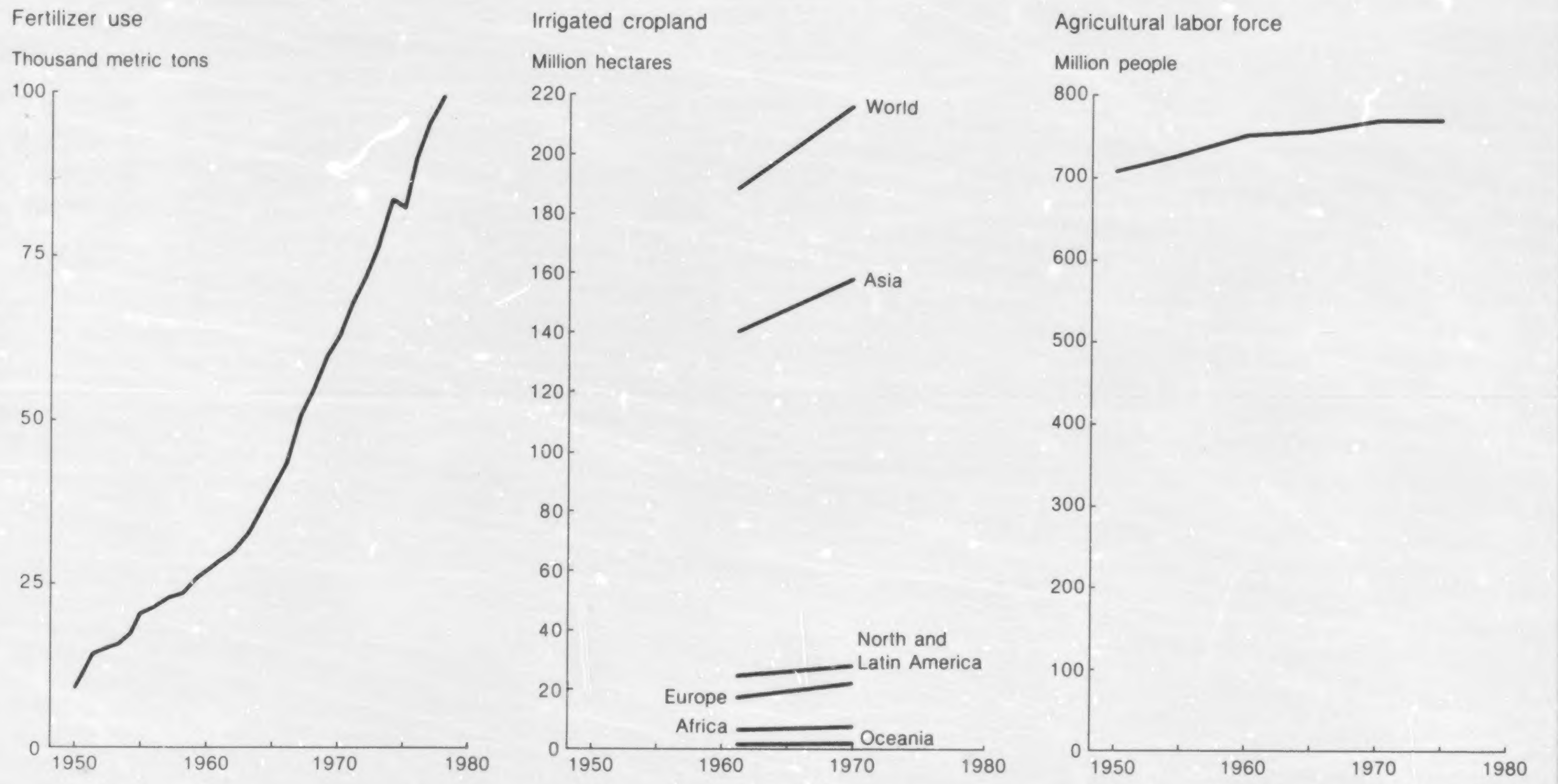
532

13-14
World agricultural production, 1954–1978



Worldwide agricultural production has grown rapidly despite the relatively small increases in arable land. Increases in the use of synthetic organic fertilizers and pesticides coupled with advances in modern plant breeding and irrigation techniques have contributed to a marked, sustained increase in average crop yields per unit of land area.

13-15
World agricultural inputs, 1950–1978



Intensive use of fertilizers and pesticides, development of new strains of corn, wheat, and rice, and expansion of irrigated lands have greatly increased the amount of cereals and other crops that can be produced on a given plot of land with approximately the same amount of farm labor. Many of the inputs required to produce the higher yields depended on formerly inexpensive sources of energy, particularly oil.

With the rapid increase in the use of technologically-enhanced agricultural inputs has come a number of environmental and resource problems.

The natural productivity of an estimated one half of the world's cropland is declining because of soil erosion, waterlogging, salinization, and other environmental problems. In certain regions, the misuse of pesticides has lead to the development of pesticide-resistant strains of pests, destroyed natural predators, killed local wildlife, and contaminated human water supplies. Improper application of fertilizers has changed the types of vegetation and fish species inhabiting nearby waterways and rivers. The availability of water may become the single most important constraint to increasing yields in the developing countries.

13-7

Major ecosystems of the world, 1970s

Ecoscience: Population, Resources, Environment, Paul R. Ehrlich, Anne H. Ehrlich, and John P. Holdren (San Francisco: W.H. Freeman and Company, 1977), fig. 4-26, pp.144–145. Adapted from *Fundamentals of ecology* (3rd ed.), E.P. Odum (Philadelphia: W.B. Saunders, 1971), and *Communities and ecosystems*, R.H. Whittaker (New York: Macmillan, 1970). Reprinted with permission.

13-8

Area and productivity of ecosystems, 1970s

See 13-7, table 4-6, p. 132, from "Carbon in the biota," R.H. Whittaker and G.E. Likens, in *Carbon and the biosphere*, G.M. Woodwell and E.V. Pecan, eds. (Washington: U.S. Atomic Energy Commission Technical Information Center, 1973), pp. 281–300.

13-9

Tropical moist forests, 1970s

"Crossroads for tropical biology," William J. Cromie, *Mosaic*, National Science Foundation, v. 10, n. 3, May/June 1979, pp. 10–11. Reprinted with permission.

13-10

Tropical moist forests, by region and country, 1945–1978

Conversion of tropical moist forests, Norman Myers, National Academy of Sciences (Washington, D.C., 1980), pp. 80, 81, 95, 97, 98, 108, 128, 132, 133, 134, 135, 156, 158.

Trends in individual countries may not be representative of an entire region.

13-11
Lands vulnerable to desertification, 1970s

World conservation strategy, International Union for the Conservation of Nature and Natural Resources with United Nations Environment Programme and World Wildlife Fund (Gland, Switzerland, 1980).

Arid and semiarid lands occupy roughly one-third of the earth's land surface. Although they vary in land forms and types of vegetation, they have low levels of precipitation (less than 20 inches of rainfall per year), with great seasonal and year-to-year variation, and relatively sparse vegetation.

Cultivation in marginal areas during periods of higher than normal rainfall is especially dangerous and may be a main cause of desertification. When dry years follow a year of plenty, ploughed soil or soil from which the sparse cover of natural plants has been eliminated is at the mercy of wind and water. The fine clays and silts are carried away and the remaining sand drifts. The social and environmental impacts are serious: Arable land is lost; wildlife is dispersed and depleted; the risk of starvation increases; and greater pressure is put on remaining lands.

13-12
World arable land, 1951-1975

The global 2000 report to the President, Council on Environmental Quality and U.S. Department of State (Washington: USGPO, 1980), v. 2, the technical report, tables 6-12, 6-13, pp. 97, 99.

13-13
Arable and potentially arable land, by region, 1970s

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, unpublished data.

LDCs are less developed countries.

13-14
World agricultural production, 1954-1978

1954-1969: *The world food situation and prospects to 1985*, U.S. Department of Agriculture (Washington: USGPO, 1974), for. agr. econ. rep. 98, p. 2.

1970-1978: *1979 Handbook of agricultural charts*, U.S. Department of Agriculture (Washington: USGPO, 1979), agr. handbook n. 561, p. 84.

Developed countries include: United States, Canada, Europe, USSR, Japan, Republic of South Africa, Australia, and New Zealand.

Developing countries include: South and Central America, Africa (except Republic of South Africa), and Asia (except Japan and communist Asia).

13-15
World agricultural inputs, 1950-1978

World fertilizer use: *1978 fertilizer yearbook*, United Nations Food and Agriculture Organization (Rome, 1979), and previous annual issues.

Irrigated cropland and world labor force: *World population trends and policies, 1977 monitoring report*, United Nations (New York, 1979), v. 1, tables 65, 69, pp. 165, 167.

Wildlife

More than 1.5 million species of plants and animals have been identified worldwide. This includes 4,100 species of mammals; 8,700 birds; 6,300 reptiles; 3,000 amphibians; 23,000 fishes; thousands of invertebrates including 800,000 species of insects; and several hundred thousand plants and fungi.

The 1.5 million is only the known number of species. Scientists continually add to the list as new lands and waters are explored and better ways are found to identify and classify species. Scientists now estimate the worldwide total to number between 3 and 10 million species.

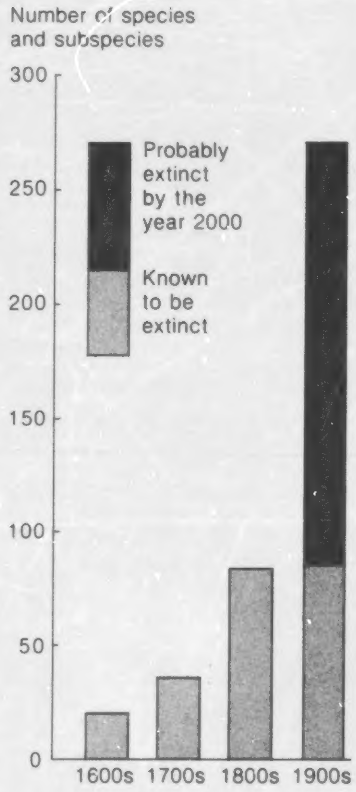
Diversity of species increases as one moves from the poles to the tropics. Some 60% to 80% of all species live in the tropics, and up to 40% live in one major ecosystem—tropical moist forests. As many kinds of plants live in Panama as in all of Europe; as many fish species live in the Amazon basin as in the whole Atlantic Ocean.

The makeup of the earth's biotic community is changing continually. Today, extinctions seem to be increasing and can be linked to man's influences on the biosphere. Man-induced extinctions are now the rule rather than the exception.

13-16
Extinct species and subspecies of vertebrate animals worldwide, 1600s-1900s

The extinction of vertebrate species has increased steadily with worldwide growth in human population and the rapid alteration of natural habitats. In the 1600s, an estimated 21 vertebrate species became extinct; in the 1700s, 36 species; and in the 1800s, 84 species. By the end of this century, an estimated 270 vertebrate species are expected to be extinct.

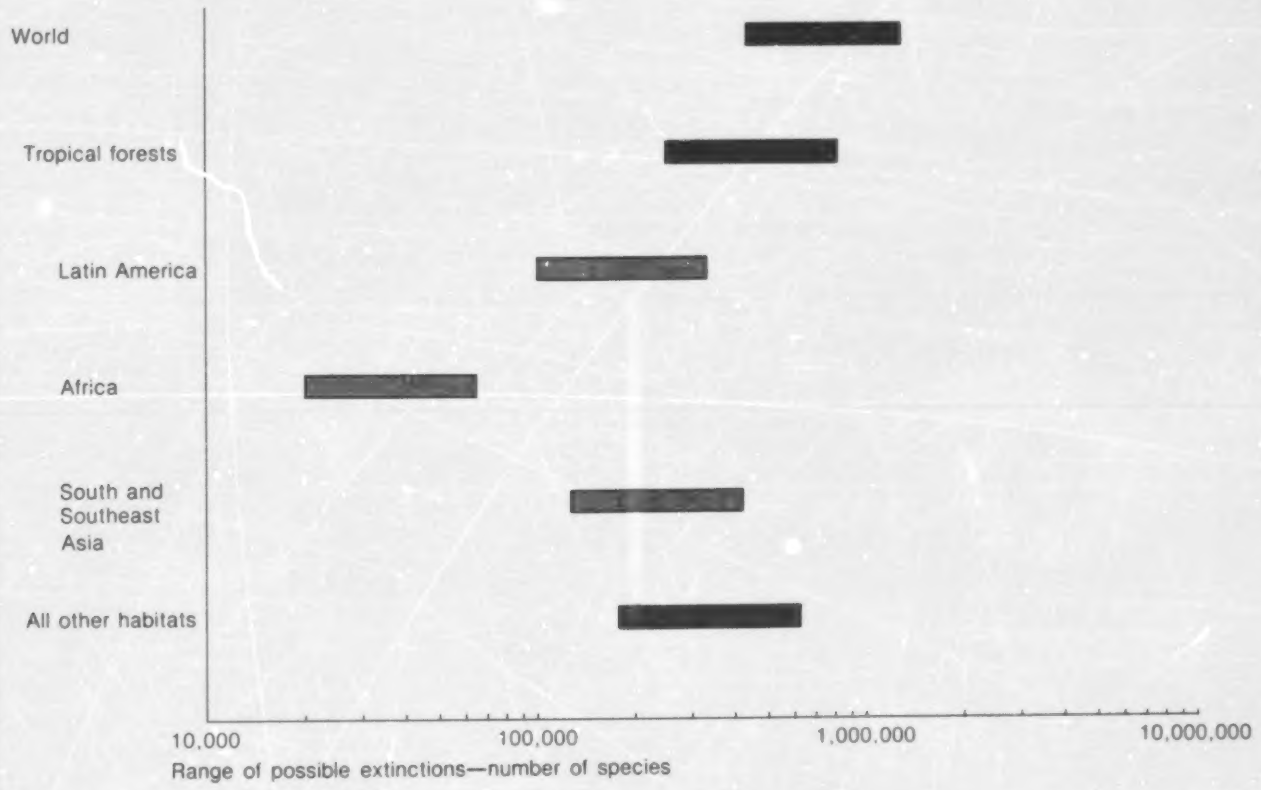
Overall, the most endangered species are those with highly restricted distributions and those requiring mature forests and grasslands.



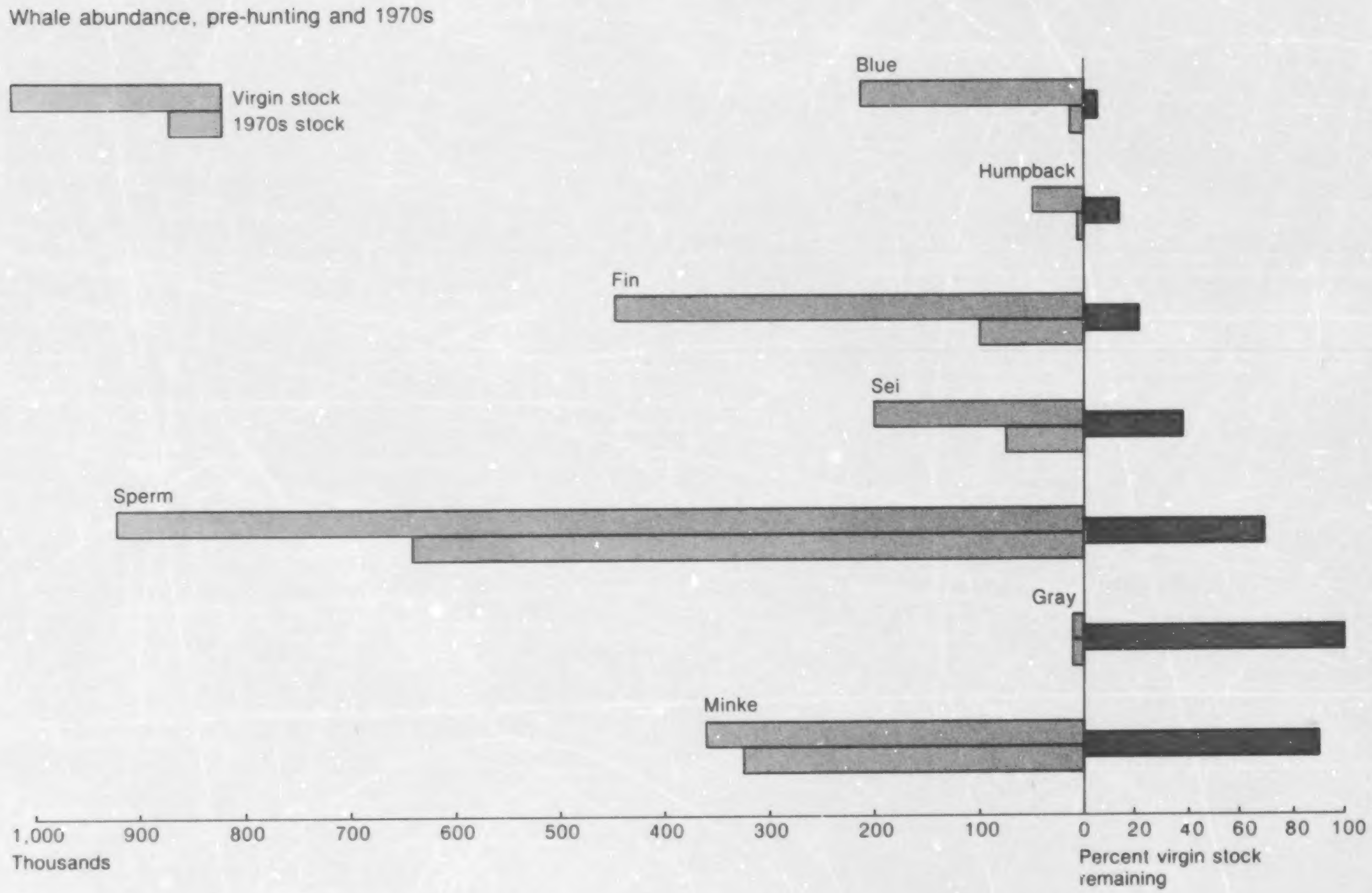
13-17
Extinction of species, by region, 1980–2000

Of the 3 to 10 million species now on earth, between 0.4 and 1.5 million species could become extinct during the next 20 years.

The largest number of extinctions is foreseen in the tropical forests, many of which are rapidly being depleted through timber harvests, the gathering of fuelwood, and conversion to cropland. The greatest number of tropical extinctions is expected among insects; the next highest number, among plants.



13-18
Whale exploitation, by species, pre-hunting through the 1970s



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545

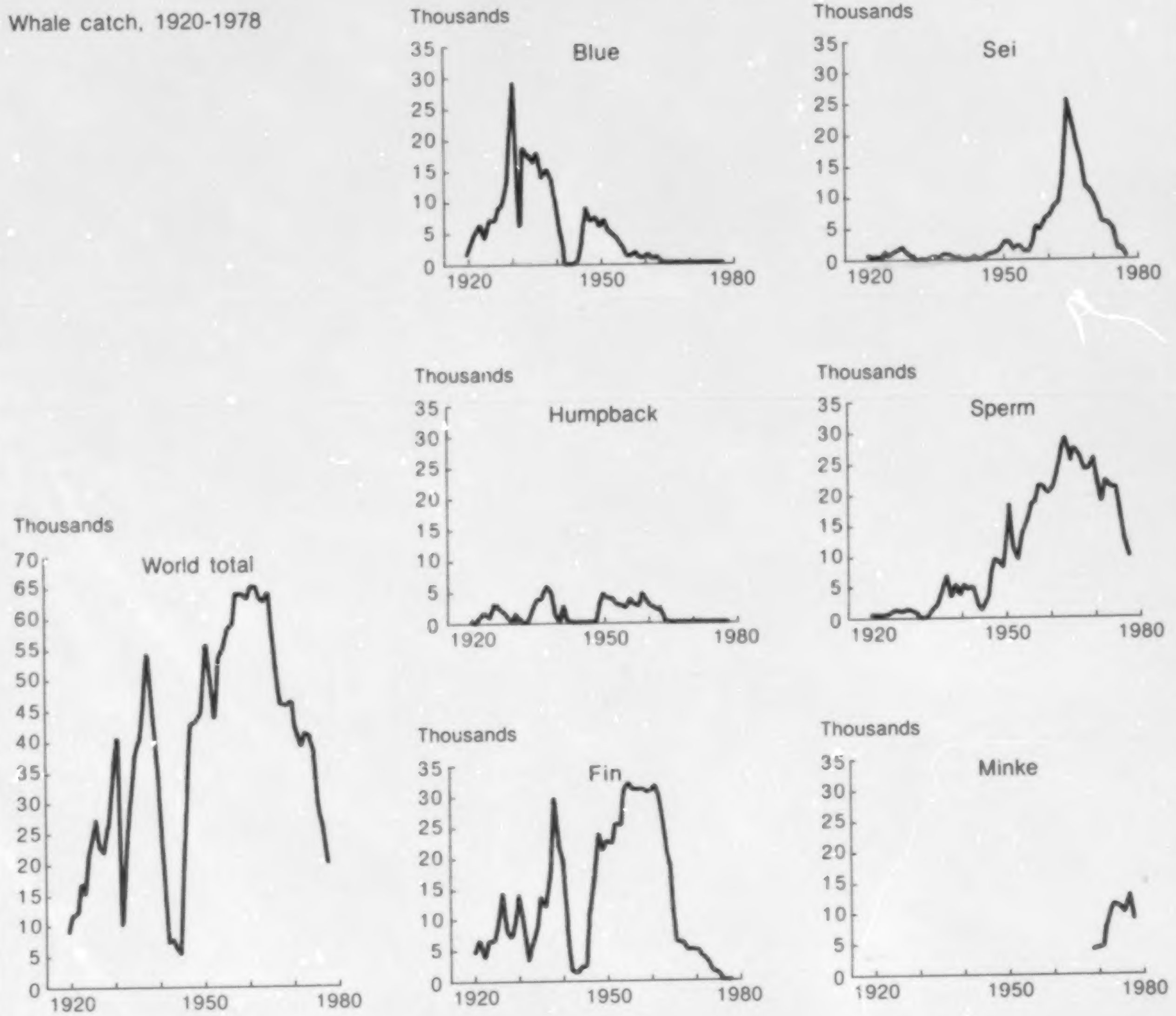
Whales are one group of mammals that have been hunted for centuries, with many species and stocks brought close to extinction.

The pattern of exploitation has been to hunt one species till it becomes too scarce to be of commercial value, then turn to another. First, the biggest whales—the blues *(Balaenoptera musculus)*—were exploited, then fin *(Balaenoptera physalus)*, humpback *(Megaptera novaeangliae)*, and sei whales *(Balaenoptera borealis)* in turn. More recently, whalers have sought sperm whales *(Physeter catodon)* and the much smaller minke *(Balaenoptera acutorostrata)*.

The world catch of whales has declined because of declining stocks and, more recently, because an international quota system now limits the catch of some species and bans the hunting of the blue, humpback, right *(Eubalaena glacialis)*, bowhead *(Balaena mysticetus)*, and gray whales *(Eschrichtius gibbosus)*. (Small subsistence catches of humpback, gray, and bowhead are allowed.)

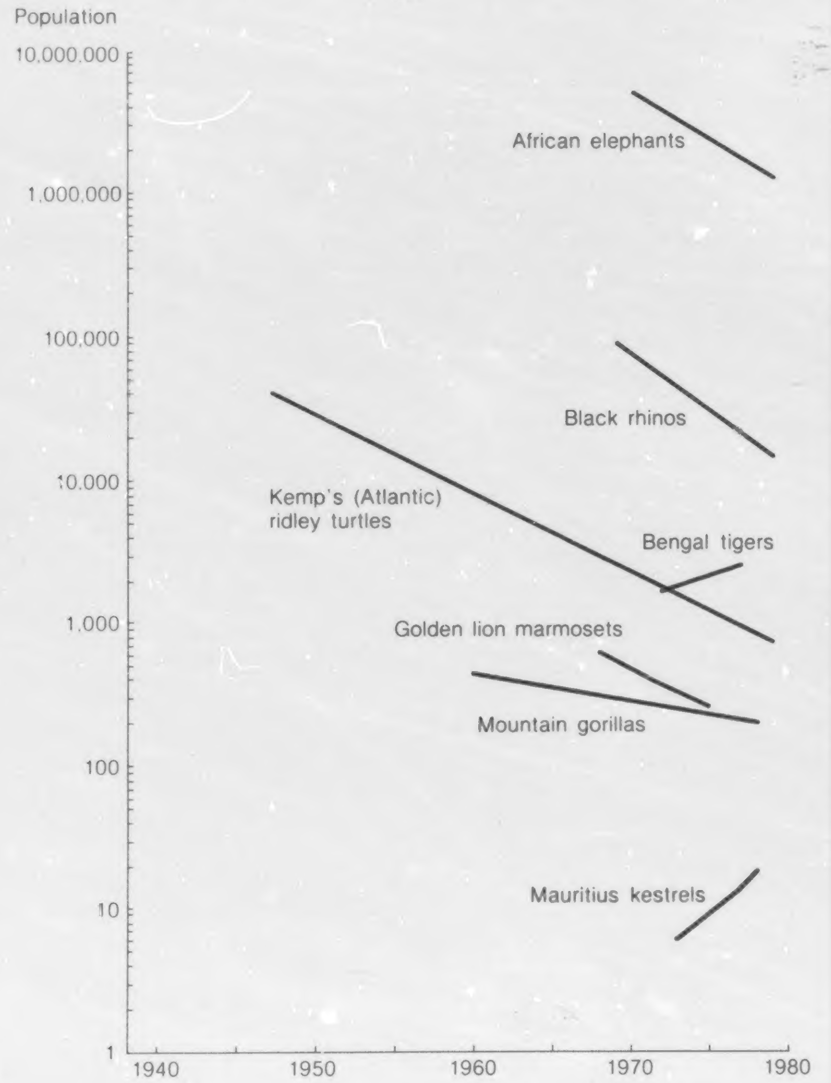
The overall quota set for the 1981 season is 13,900 whales, a sharp decline from the 46,600 killed per year a decade earlier. But even with protection, there is little sign that whale stocks, except for the California gray whale *(Eschrichtius robustus)*, are recovering.

Whale catch, 1920-1978



13-19

Population of selected endangered and threatened species, 1947–1979



Populations of many birds and large mammals are dangerously low. This results from habitat disturbance and destruction, pollution, increased competition from introduced species, and overharvest. Among vertebrates, the International Union for the Conservation of Nature and Natural Resources has identified 948 species as endangered, vulnerable, or rare. The list includes 270 mammals, 363 birds, 28 amphibians, 108 reptiles, and 179 fish. It does not include thousands of invertebrate species which are believed to be endangered and more than 25,000 vascular plants regarded as endangered, threatened, or rare.

A number of well-known endangered and threatened animals for which data are available have been selected.

The African elephant *(Loxodonta africana)* is found in an area of about 3 million square miles throughout most of the continent. A century ago, estimates placed the number of African elephants at nearly 10 million. In 1975, there were an estimated 5 million. The latest survey (1979) reports that populations have decreased to about 1.3 million. Evidence of massive slaughters have been seen in Uganda. Poaching for ivory and the loss of habitat to new farmlands, other development, and desertification are also responsible for bringing about a decline in the African elephant populations.

The black rhinoceros *(Diceros bicornis)* lives in 17 countries in eastern and southern Africa. It is killed primarily for its horn. Measures are being taken by African countries and others to protect the black rhinoceros and control illegal horn trade.

The Bengal tiger *(Panthera tigris tigris)* is protected over much of its range in southern Asia, but protection is not always enforced. In India, as a result of strict enforcement, the population increased from 1,827 animals in 1972 to 2,484 in 1978. Its forest habitat continues to be altered by expanding agriculture and urban settlements.

Six of the seven species of sea turtles are endangered. Kemp's (Atlantic) ridley turtle *(Lepidochelys kempi)* is the most endangered. There are at present 500 to 1,000 nesting females on a beach in Mexico. Scientists are trying to create another nesting beach at Padre Island National Seashore in Texas. Because the sea turtle is migratory, a global strategy is needed to protect the remaining population.

The mountain gorilla *(Gorilla gorilla beringei)* lives only in the forested, mountainous areas of western Rwanda, southwest Uganda, and eastern Zaire in central Africa. In 1960, estimates placed their numbers at 400 to 500; as few as 200 were thought to exist in 1978, most of these in Rwanda. Its range is mostly within national parks and game reserves, but these areas are under stress from expanding cattle grazing and banana plantations.

The golden lion marmoset *(Leontopithecus rosalia rosalia)* is native to Brazil's southeastern forest and is presently restricted to areas near Rio de Janeiro. These areas are being logged and cleared for development. In 1968, the number of golden lion marmosets was estimated at 600; in 1971, at 400. Wild populations were thought to be down to about 250 in 1975. Brazil offers legal protection and has regulated the export of this endangered monkey. Captive breeding programs have been successful both in Brazil and the United States.

The Mauritius kestrel *(Falco punctatus)*, a bird native only to the Indian Ocean island of Mauritius, had a total population of 6 in 1974. Because of protection efforts and breeding programs, 19 birds existed in 1978, 6 in captivity and 13 in the wild. The long-term decline in the kestrel population paralleled the decrease in the extent of forests and the predation by animals introduced to the island.

13-16
Extinct species and subspecies of vertebrate animals worldwide, 1600s–1900s

"Breaking the web," George Uetz and Donald L. Johnson, *Environment*, v. 16, n. 10, December 1974, p. 33, from J.A. Davis, New York Zoological Society, the Zoological Park, Bronx Park, New York, January 1972; and from *Red data books*, International Union for the Conservation of Nature and Natural Resources (Lausanne, Switzerland), various issues.

13-17
Extinction of species, by region, 1980–2000

The global 2000 report to the President, Council on Environmental Quality and U.S. Department of State (Washington: USGPO, 1980), v. 2, the technical report, table 13-30, p. 331.

Projections assume a low deforestation case from 1975 to the year 2000. Of the total of 3 to 10 million species, 10% are in the virgin forests of the Amazon, 5% in African tropical forests, 10% in South and Southeast Asian tropical forests, and 75% in oceans, fresh water, nontropical forests, islands, etc.

13-18
Whale exploitation, by species, pre-hunting through the 1970s

Whale abundance: "The status of whales," Victor B. Scheffer, *Pacific discovery*, v. 29, n. 1, 1976, p. 3.

Whale catch, 1920–1970, except minke: *The whale problem: A status report*, William E. Schevill, ed. (Cambridge, Mass.: Harvard University Press, 1974), table 13-1, pp. 306–307. 1971–1978, except minke: *International whaling statistics*, Committee for Whaling Statistics (Sandefjord, Norway, 1979), LXXXIII, table b, p. 12. 1969–1978, minke: *International whaling statistics*, Committee for Whaling Statistics (Sandefjord, Norway, 1979), LXXXIII, table Z^2, p. 27.

Catch data for minke are not available for years prior to 1968.

13-19
Population of selected endangered and threatened species, 1947–1979

African elephant: "African elephants slaughtered," Baynard Webster, *New York Times*, June 10, 1980, pp. C1–C2.

Black rhinoceros: "Rhinoceros background sheet," World Wildlife Fund (Washington, D.C., September 1979), p. 4, from International Union for the Conservation of Nature and Natural Resources.

Bengal tiger: *Red data book*, International Union for the Conservation of Nature and Natural Resources (Gland, Switzerland, 1972), v. 1. *World wildlife yearbook 1978–1979*, World Wildlife Fund (Morges, Switzerland, 1979), p. 59.

Kemp's (Atlantic) ridley sea turtle: "Experts gather to talk turtle," Constance Holden, *Science* 206:1383–1384 (December 21, 1979).

Mountain gorilla: "Mountain gorilla *(Gorilla gorilla beringei)* status (1980) with some reference to other gorilla species," Diane Fossey, June 1980, p. 2. "Endangered mountain gorillas killed, raising the possibility of poachers," Thomas O'Toole, *Washington Post*, July 30, 1978.

Golden lion marmoset: *Red data book*, International Union for the Conservation of Nature and Natural Resources (Gland, Switzerland, 1974), v. 1. "Will the pot of gold have a rainbow?," Devra G. Kleinman, *Animal Kingdom*, New York Zoological Society, February/March 1976, p. 4.

Mauritius kestrel: *World wildlife yearbook 1978–1979*, World Wildlife Fund (Morges, Switzerland, 1979), p. 137.

The International Union for the Conservation of Nature and Natural Resources (IUCN) defines endangered species as those "in danger of extinction and whose survival is unlikely if the causal factors continue operating." Vulnerable species are "likely to move into the endangered category in the near future if the causal factors continue operating." Rare species have "small world populations that are not at present endangered or vulnerable but are at risk." (*Red data book*, International Union for the Conservation of Nature and Natural Resources (Gland, Switzerland, 1977), v. 2, preamble 3.)

All 7 species shown here, except the African elephant, are listed as endangered by the IUCN. The African elephant is listed as threatened (comparable to IUCN's category of vulnerable) by the U.S. Fish and Wildlife Service.

Black rhinoceros data are for those in Kenya and Tanzania only, but similar declines are occurring throughout the rhinoceros's range.

Bengal tiger data are for those in India only.

Kemp's (Atlantic) ridley sea turtle data are for nesting females.

Marmosets are also called tamarins.

Oceans

The oceans of the world cover more than two-thirds of the earth's surface. They contain more than 97% of the world's water. Oceans moderate and influence the earth's climate and provide most of the water vapor that returns to the earth as rain. One-third of the planet's oxygen comes from marine phytoplankton. Marine fish may provide as much as 10% of the animal protein consumed by humans. The oceans are also the earth's principal filtering system. They decompose and recycle wastes from rivers and streams and are the final burial site for most materials that are not recycled.

The world's oceans can be divided into two zones: coastal and open. The coastal zone constitutes about 10% of the total ocean area and includes waters covering the continental shelves and slopes. Coastal waters are rich with sea life, from microscopic phytoplankton to great schools of fish. They are also the receptacle for wastes from rivers, direct runoff from the land, oil spills, and ocean dumping. When pollution occurs in marine waters, it is most likely to be observed first in the coastal waters, and its effects are likely to to be serious there.

The deep waters of the open ocean, usually 300 feet (91 meters) or more in depth, are mostly out of contact with coastal water and surface waters. The mixing of the deep and surface waters may take hundreds, even thousands of years, depending on the basin involved. Much of the manmade wastes dispersed to the open ocean are still in the water column: litter, plastic, and oil slicks are found in surface waters. DDT and other chlorinated hydrocarbons are found in open ocean organisms; and radioactive isotopes of strontium and cesium from nuclear bomb detonations can now be found at depths of 1,000 meters. The open ocean changes slowly, but once changes do occur, they are not likely to be reversed quickly nor modified easily by humans.

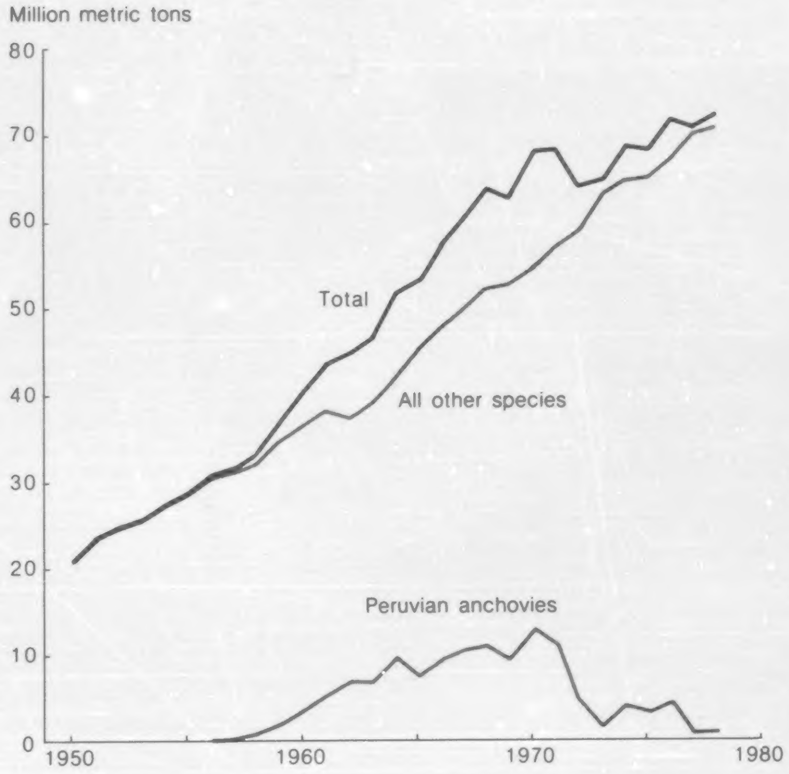
13-20
World commercial fish catch, 1950–1978

World fish catch is 92% from marine waters and 8% from fresh waters.

Fish catch increased dramatically from the 1950s to the early 1970s. The sharp decline was a result of the precipitous drop in the harvest of anchovies *(Engraulus ringens)* off the coast of Peru. This fishery was almost eliminated by overfishing and by a rapid influx of warm water in 1972, which greatly reduced nutrient levels and numbers of fish. The anchovy fishery has not recovered, and less than 1 million tons are harvested yearly.

Except for anchovies, the world fish catch has continued to increase, but the kinds of species harvested have changed over the years. There has been a decline in some of the most prized fin fish species, such as the Atlantic cod and the flounder, and an increase in crustaceans (shrimp, crabs) and mollusks (clams and oysters).

Increasingly, countries are managing their fisheries. The United Nations Food and Agriculture Organization estimates that the world fishery yield of conventional species could be sustained at about 120 million metric tons per year if all countries were to manage their fisheries on an optimum basis. (Optimum yield means that the catch is regulated to ensure the greatest overall benefit to society in terms of food production and recreational opportunities over the long term.) Other experts predict that world fish catch cannot be sustained much above the current production level of 75 million metric tons per year.



553

13-21

Areas of marine pollution, 1970s

Despite their vast extent, oceans can be polluted and degraded. Most marine pollution originates on land and passes through the coastal zone first—through river discharges to bays and estuaries, through direct discharges from coastal outfalls, and from vessel discharges as a result of deliberate dumping or accidents. The atmosphere also transports pollutants from land to sea, particularly radioactive fission products (cesium-137, strontium-90), metallic compounds (tetraethyl lead), and synthetic chemicals (DDT).

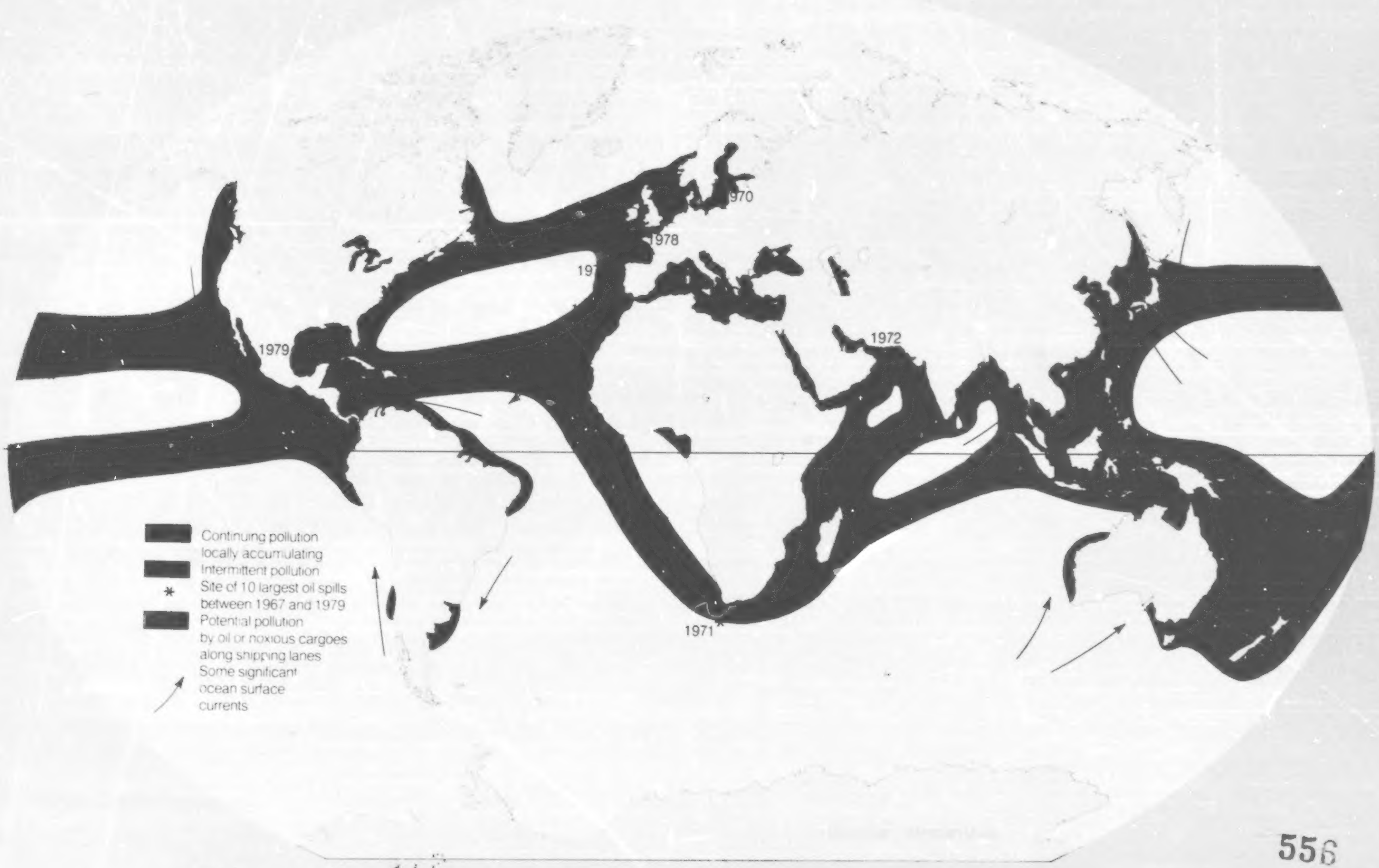
Marine pollutants can be classified into five categories: metals, synthetic chemicals, petroleum hydrocarbons, radionuclides, and solid wastes. The effect of a pollutant depends on where it is disposed (garbage and litter can greatly reduce the quality of an estuary but may have less effect in open ocean), how long it stays in the water, and the nature of the substance itself.

Coastal pollution occurs primarily in areas of high population density, concentrated industrial activity, and along major shipping lanes where intentional discharges are the most prevalent source of spills. Half of all oil tanker accidents, too, are in ports or port approaches along heavily traveled shipping lanes in Japanese, North American, and European waters.

Most materials dumped into the oceans are decomposed or recycled through natural processes. Much of the material is finally deposited in bottom sediments, where it remains unless disturbed and reintroduced into the water column. Radioactive isotopes, DDT, and other synthetic organic compounds are not easily decomposed; they can build up in the water and sediments and accumulate in the tissue of ocean organisms.

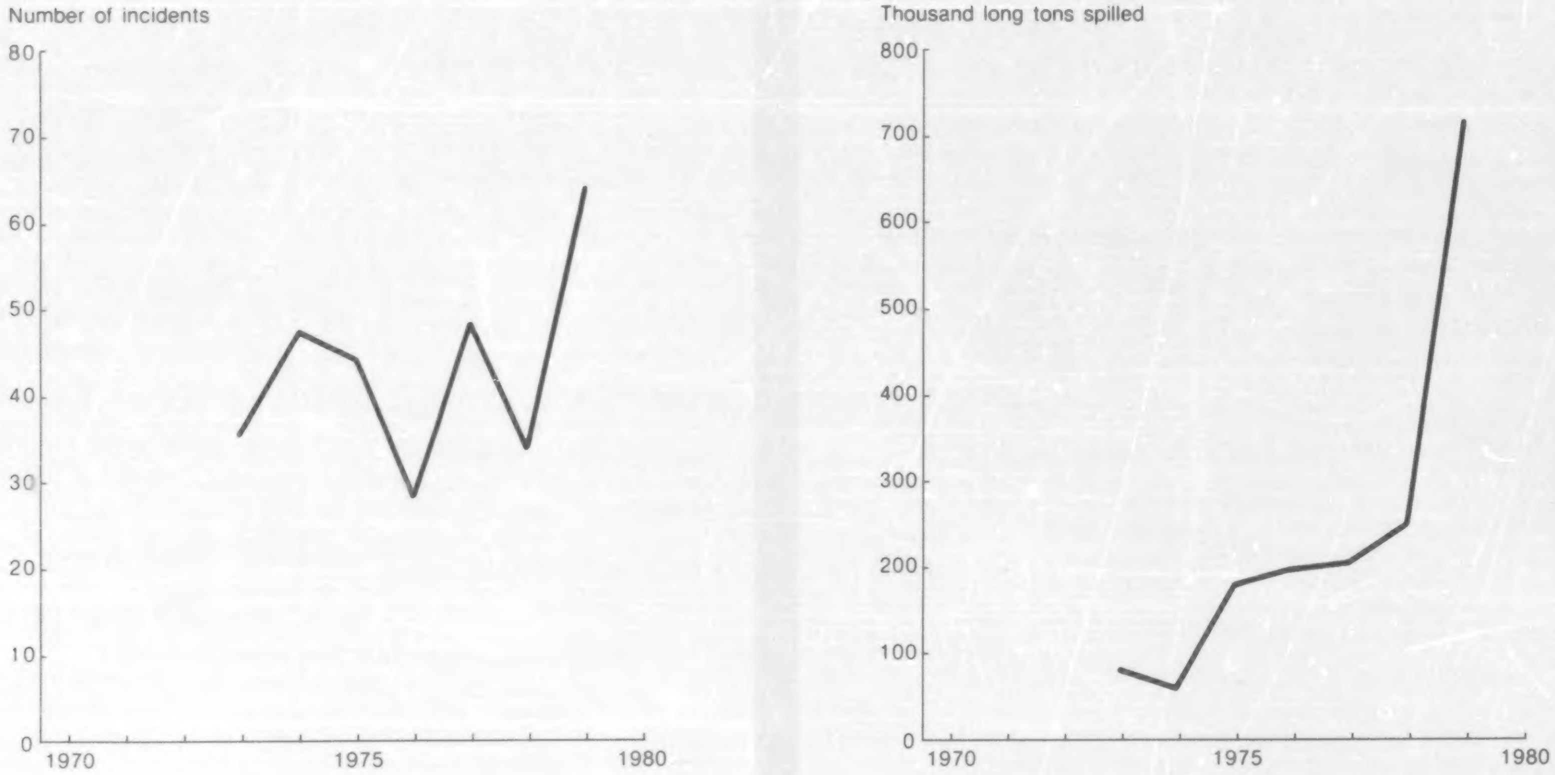
Attempts to control ocean pollution have been aimed primarily at oil and radioactivity. More recently, control of dumping wastes at sea has been instituted. Under the London Convention of 1972, 40 signatory countries now issue permits for ocean dumping of dredge spoils, sewage sludge, and industrial wastes. Special permits are required for dumping of low-level radioactive wastes. No high-level radioactive waste dumping is permitted.

There is no global international convention covering land-based sources of pollution entering the water or the atmosphere, but initial steps are being taken. In May 1980, nations bordering the Mediterranean Sea signed an agreement on the protection of the Mediterranean from land-based pollution. However, pollution from rivers and coastal outfalls is still largely untouched internationally.


1970
1978
197
1979
1972
1971*
Continuing pollution locally accumulating
Intermittent pollution
* Site of 10 largest oil spills between 1967 and 1979
Potential pollution by oil or noxious cargoes along shipping lanes
Some significant ocean surface currents

13-22

World oil spills from tankers, 1973–1979



Oil is discharged into the world's oceans from atmospheric fallout, land-based runoff, routine tanker and ship operations, tanker accidents, and offshore drilling activities.

The amount of oil reported spilled into oceans from tanker accidents has been increasing, but one large spill can so influence the data that trends are not easy to discern. The large increase in the amount of oil spilled from tankers in 1979, for instance, resulted primarily from the collision of two supertankers, the *Atlantic Empress* and the *Aegean Captain*, in which 158,000 tons of crude oil were discharged into the Caribbean, 50 miles northwest of Tobago.

In addition, an enormous amount of oil—325,000 tons (more than 100 million gallons)—was spilled in the oil well blowout in Campeche Bay, off Mexico, during 1979 and 1980.

Tanker accidents account for a relatively small portion of the oil discharged into the sea from tankers. Cleaning and ballasting operations are believed to discharge several times more oil in volume, but as international regulations tighten and as the value of "waste" oil in tank washings increases, these forms of oil pollution are likely to diminish.

13-20
World commercial fish catch, 1950–1978

Fisheries of the United States, 1979, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (Washington: USGPO, 1980), p. 24.

Total includes marine and fresh water fish.

13-21
Areas of marine pollution, 1970s

Continuing, intermittent, and potential pollution: *Pollution and international problems for fisheries*, United Nations Food and Agriculture Organization (Rome, 1971), world food problems, n. 14, fig. 1.

Ten largest oil spills: News release, U.S. Coast Guard, September 1979, *Oil spill intelligence report*, Center for Short-Lived Phenomena, Cambridge, Mass. (August 10, 1979), v. 2, n. 32, p. 2.

Sites of major spills shown on the map refer to the 10 largest tanker accidents and oil well blowouts between 1967 and 1979. At least 60,000 tons of oil were lost in each spill.

13-22
World oil spills from tankers, 1973–1979

"Newsletter—worldwide tanker losses and oil spills—full years," Tanker Advisory Center, Inc., New York (April, 1980).

Data are based on reports by agents of Lloyd's of London. These include accidents resulting in insurance claims and other known accidents in oceans, estuaries, and fresh water. Accidents were caused by weather damage, strandings, collisions, other contact (rammed dock or moored vessel), fires and explosions, machinery damage, and other mishaps (lost anchor, crew negligence, steering trouble, breakdown at sea, etc.).

Data are for accidental spills from tankers, ore/oil carriers, and bulk/oil carriers capable of carrying at least 6,000 tons of cargo and fuel oil. Operational discharges (for example, those occurring when tanks are cleaned) and spills from liquid gas carriers are excluded.

Atmosphere

The atmosphere acts as a transport medium for the cycling of many chemicals essential to life—oxygen, carbon dioxide, water vapor, nitrogen, and a variety of trace elements. It also filters incoming ultraviolet radiation and traps outgoing infrared radiation, thus making the earth habitable.

The state of the atmosphere can be disturbed by natural forces, such as volcanoes and dust storms, changes in solar radiation, and by human activities, such as the large-scale combustion of fossil fuels.

Most atmospheric pollution is local or regional. But two problems are global: the growing quantities of chlorofluorocarbons that are being emitted and dispersed into the upper atmosphere, where they can cause the breakdown of stratospheric ozone, thus permitting increased ultraviolet radiation to reach earth; and the increasing atmospheric concentration of carbon dioxide, which may have long-term impacts on the earth's climate. In both cases, the changes are very gradual, are not well understood, and are difficult to measure, but, once underway, they may be virtually impossible to reverse.

13-23

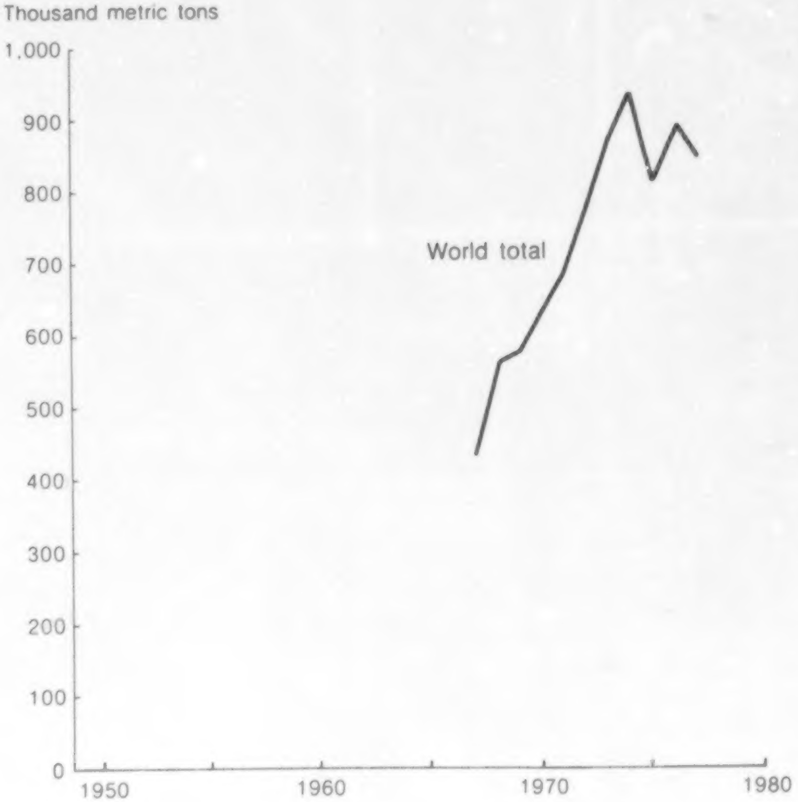
Chlorofluoromethane production, 1967–1977

Chlorofluoromethanes (CFMs), a group of chlorofluorocarbons, are used as propellants in aerosols, as refrigerants, and as blowing agents for insulation and other foam products. CFMs in spray aerosols are released directly into the atmosphere. Those in air conditioning and refrigeration systems and in foam products leak into the atmosphere from poorly maintained systems and ill-managed disposal.

Once in the atmosphere, CFMs slowly diffuse into the stratosphere, the layer about 5 to 30 miles above the earth. There, CFMs disassociate, releasing free chlorine that reacts with ozone, causing it to degrade into free oxygen. Ozone screens the earth from much of the sun's damaging ultraviolet radiation. The ozone concentration in the stratosphere is estimated to have already declined by 2% as a result of reaction with CFMs.

After steady and rapid growth, world production of CFMs has remained at roughly pre-1973 levels, largely as a result of a U.S. ban on their use in aerosol propellants. Four other countries have limited the production of CFMs for use in aerosols: the Netherlands, Canada, Sweden, and West Germany. Since CFMs do not easily break down into other compounds in the lower atmosphere, the cumulative amount in the stratosphere probably continues to grow.

With the present release rates of CFMs, it is estimated that stratospheric ozone could be reduced by 16.5% within the next century, causing a 44% increase in the amount of ultraviolet radiation reaching earth. These changes would increase the potential for health hazards, including a 50% to 100% increase in the incidence of skin cancer, a decline in the yield of some crops, and damage to aquatic ecosystems.



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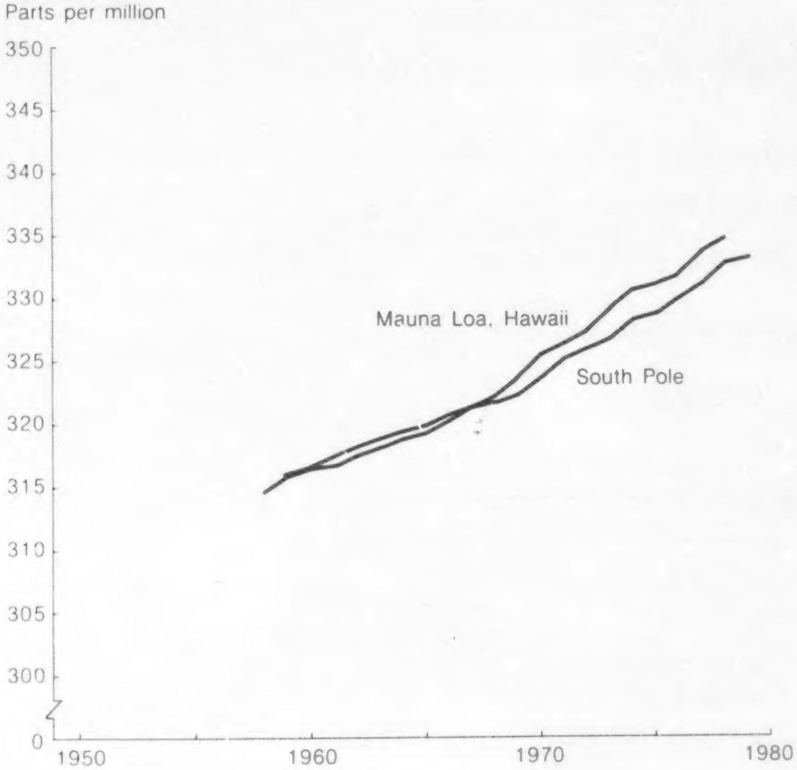
13-24
Carbon dioxide concentrations in air, 1958–1979



The biosphere contains a complex mixture of carbon compounds in a continuous state of formation, transport, and decomposition. A central role in this carbon cycle is played by carbon dioxide (CO_2), which is taken from the atmosphere and used by plants to synthesize food. When plants are consumed by animals or decomposed, CO_2 is released back to the atmosphere. A similar carbon cycle takes place in the oceans, where CO_2 dissolves in water, is taken up by phytoplankton during photosynthesis and released to the water during respiration and decay.

Largely because of increased burning of fossil fuels, CO_2 concentrations in the atmosphere are increasing. Readings at Mauna Loa, Hawaii, and at the South Pole, Antarctica, show a 7% increase over the past 21 years. Since the beginning of the industrial era, CO_2 concentrations in the atmosphere have increased by 15% to 25%.

CO_2 concentrations may double over preindustrial concentrations by the year 2050 if global fossil fuel use were to grow at 2% per year. Increasing rates of deforestation may add to this trend. With an increase in CO_2 concentrations, some of the radiant heat that is reflected from the earth back into space would be held in the lower atmosphere. If a doubling of the CO_2 concentration were to occur, average global temperatures near the ground would be expected to rise a few degrees celsius. As a result, there could be significant geographical shifts in the location of agriculturally favorable areas. With an increase in temperatures, ice sheets and glaciers might begin to melt, with ocean levels increasing by several feet over the following century.

Changes in temperature caused by increased CO_2 concentrations that would have occurred over the past 100 years may be too small to be distinguished from natural warming and cooling cycles and the thermal inertia of the oceans. However, by the time a definite CO_2-induced warming trend is detected, it could be very difficult to avoid or reverse the climate changes because of the slow rate at which CO_2 is removed from the atmosphere by the oceans.

13-23
Chlorofluoromethane production, 1967–1977

Stratospheric ozone depletion by halocarbons: Chemistry and transport, National Academy of Sciences (Washington, D.C., 1979), p. 21.

Chlorofluoromethane production shown includes the total of the compounds F-11, F-12, and F-22, which are about 95 percent of the chlorofluoromethanes produced.

13-24
Carbon dioxide concentrations in air, 1958–1979

"Atmospheric carbon dioxide concentration, the observed airborne fraction, the fossil fuel airborne fraction, and the difference in hemispheric airborne fractions," R. B. Bacastow and C. D. Keeling, in *Scope 16: Global carbon modelling*, B. Bolen, ed. (London: John Wiley and Sons, 1981).

List of illustrations

Chapter 1
People and the land

Land and climate

1-1 Physical characteristics of the United States, *2*
1-2 Climatic zones of the United States, *3*

Population totals and distribution

1-3 Population distribution, 1970, *4*
1-4 Total population, 1900–1978, and projected to 2025, *5*
1-5 Population growth rates, 1900–1978, *5*
1-6 Population, by region, 1950–1978, *6*
1-7 Population growth rates, by region, 1950–1978, *6*
1-8 Population density along major coasts, 1976, *7*
1-9 Increase in population density along major coasts, 1940–1976, *7*
1-10 Population in urban and rural areas, 1900–1950, and in metropolitan and nonmetropolitan areas, 1950–1978, *8*
1-11 Metropolitan areas with population increases of 20% or more, 1970–1977, *9*
1-12 Population migration, 1970–1978, *10*
1-13 Population growth rates in metropolitan and nonmetropolitan counties, 1950–1977, *10*
1-14 Population change in nonmetropolitan counties, 1970–1977, *11*
1-15 Urban regions, 2000, *12*

Chapter 2
Critical areas

Wetlands

2-1 Natural wetlands, 1954, *16*
2-2 Total wetland acreage, presettlement to 1971, *18*
2-3 Wetland acreages, selected States, 1850–1975, *19*
2-4 Use of filled wetlands, Maine to Delaware, 1955–1964, *19*
2-5 State programs protecting wetlands and coastal areas, 1978, *20*

Wild areas

2-6 National Wilderness Preservation System, 1978, *22*
2-7 Designated and proposed wilderness areas, 1964–1979, *24*
2-8 National Wild and Scenic Rivers, 1978, *25*
2-9 The National Wild and Scenic Rivers System, 1968–1978, *26*
2-10 The National Park System, 1979, *28*
2-11 National Park Service units, 1872–1978, *30*
2-12 National and State park acreages, 1872–1978, *31*
2-13 Representation of natural regions in the National Park System, 1970, *32*
2-14 Visits to National and State parks, 1954–1978, *33*
2-15 Overnight stays in National Park Service-operated campgrounds, 1960–1978, *34*
2-16 The 10 most popular National Parks, 1978, *35*

Historic places

2-17 Properties on the National Register of Historic Places, 1968–1978, *36*
2-18 Properties on the National Register of Historic Places, by type, 1978, *37*
2-19 Properties removed from the National Register of Historic Places, 1971–1978, *37*

Risk zones

2-20 Urban population and lands affected by stream flooding, by Water Resources Region, 1967, *39*
2-21 Hurricane risk along the Gulf and Atlantic coasts, *40*
2-22 Frequency of tornadoes, 1953–1962, *41*

2-23 Earthquake risk zones, *41*
2-24 Loss of life from selected natural disasters, 1900–1977, *42*
2-25 Property damage from selected natural disasters, 1900–1977, *43*

Chapter 3
Human settlements

Settlement patterns

3-1 Standard Metropolitan Statistical Areas, 1950, *46*
3-2 Standard Metropolitan Statistical Areas, 1978, *47*
3-3 Population in suburban areas and central cities, 1940–1978, *48*
3-4 Population density, by location, 1940–1978, *48*
3-5 Land use in Standard Metropolitan Statistical Areas, by region, 1970, *49*

Housing units

3-6 Composition of housing stock, by type of unit and location, 1977, *50*
3-7 Composition of housing stock, by type of unit, 1940–1977, *50*
3-8 Occupied housing units, 1900–1977, *51*
3-9 Occupied housing units, per 100,000 population, 1900–1977, *51*

Housing conditions

3-10 Characteristics of new single-family housing units, 1966–1978, *52*
3-11 Characteristics of new multifamily housing units, 1971–1978, *53*
3-12 Condition of housing, 1940–1977, *54*
3-13 Homes with selected major electric appliances, 1950–1977, *55*
3-14 Overall opinion of living unit, by location, 1977, *56*

Neighborhood conditions

3-15 Overall opinion of neighborhood, by location, 1977, *56*
3-16 Inadequate neighborhood services, 1973–1977, *57*
3-17 Neighborhood deficiencies, 1973–1977, *58*

Chapter 4
Transportation

Transportation systems

4-1 Major transportation networks, 1925–1978, *62*
4-2 Transportation vehicles, *62*
4-3 Sales of specialized vehicles, 1961–1978, *63*

Use of the system

4-4 Local passenger travel, 1950–1975, *63*
4-5 Principal means of transportation to work, 1960–1977, *64*
4-6 Principal means of transportation to work, by location, 1977, *64*
4-7 Intercity passenger travel, 1929–1977, *65*
4-8 Intercity freight transportation, 1929–1977, *65*
4-9 Major pipelines, 1975, *66*

Impacts on the environment

4-10 Energy consumption, by mode of transportation, 1965–1977, *67*
4-11 Energy intensity for freight transportation, 1976, *68*
4-12 Energy intensity for local and intercity passenger travel, 1976, *68*
4-13 Automobile fuel economy and standards, 1940–1985, *69*
4-14 Automobile emissions and standards, 1957–1985, *70*
4-15 Noise levels of surface transportation vehicles, 1971, *71*
4-16 Population exposed to noise at 23 major airports, 1972, *72*

Chapter 5
Material use and solid waste

Material use

5-1 Flow of materials, products, and solid wastes, 1977, *77*
5-2 U.S. material consumption, 1948–1978, *78*
5-3 U.S. material consumption in relation to gross national product, 1948–1978, *80*
5-4 U.S. material consumption per capita, 1948–1978, *82*

Solid waste

5-5 Solid wastes disposed of by manufacturing industries, 1974–1977, *84*
5-6 Hazardous waste generated by selected industries, 1975, *85*
5-7 Industrial hazardous waste generation, by EPA Region, 1975, *85*
5-8 Consumer solid wastes disposed of and recycled, 1960–1978, *86*
5-9 Consumer solid wastes disposed of, by materials, 1978, *86*
5-10 Recycled consumer solid wastes, by material, 1960–1978, *87*

Chapter 6
Toxic substances

6-1 Selected toxic substances, *90*

Pesticides

6-2 Synthetic organic pesticide production, by type, 1950–1978, *92*
6-3 Insecticide production, by type of chemical, 1960–1978, *93*
6-4 Selected herbicides used by farmers on crops, 1964–1976, *94*
6-5 Selected insecticides used by farmers on crops, 1964–1976, *95*
6-6 Pesticide residues in river water and sediments in Texas, Louisiana, and Oklahoma, 1968–1976, *96*
6-7 Pesticide residues in fish and birds, 1966–1976, *97*
6-8 Pesticide residues in human tissue, 1970–1976, *98*

Industrial chemicals

6-9 Production of selected industrial chemicals, 1950–1978, *100*
6-10 Flow of asbestos in the environment, *101*
6-11 PCB residues in fish and birds, 1969–1976, *102*
6-12 PCB residues in human tissue, 1972–1976, *102*
6-13 Cancer deaths associated with vinyl chloride and polyvinyl chloride, 1942–1973, *103*
6-14 Cancer deaths associated with asbestos, 1959–1977, *104*

Metals

6-15 Primary demand for selected metals, 1954–1978, *106*
6-16 Flow of mercury in the environment, *107*
6-17 Cancer deaths associated with metals, 1940–1973, *108*

Radiation

6-18 Radiation exposure, by source, 1970, *110*
6-19 Radiation levels from nuclear fallout as measured by strontium-90 and cesium-137 in pasteurized milk, 1960–1978, *112*
6-20 Radiation levels from nuclear power generation, as measured by krypton-85 in air, 1962–1976, *112*
6-21 Radiation exposure of special population groups, *113*
6-22 Relative risk of cancer from radiation, 1946–1974, *114*

Chapter 7
Cropland, forests, and rangeland

Cropland

7-1 Cropland, *118*
7-2 Uses of cropland, 1949–1978, *119*
7-3 Prime farmland, 1975, *119*
7-4 Prime farmland lost to urbanization and water projects, by farm production region, 1967–1975, *120*
7-5 Agricultural production, 1960–1978, *121*
7-6 Agricultural inputs, 1950–1978, *122*
7-7 Sheet and rill erosion from water on cropland by State, 1977, *124*
7-8 Wind erosion on cropland in the Great Plains States, 1977, *124*

Forests

7-9 Forests, *126*
7-10 Ownership of forest land, 1977, *127*
7-11 Commercial forest land, by region and ecosystem, 1977, *128*
7-12 Sawtimber growth and harvest, by type, 1952–1976, *130*
7-13 Sawtimber growth and harvest, by region and ownership, 1952–1976, *131*
7-14 Sawtimber growth and harvest in two regions, by ownership, 1952–1976, *132*
7-15 Roundwood harvest, by product, 1950–1976, *133*
7-16 Forest conditions, 1950–1978, *134*
7-17 Recreational use of the National Forests, 1965–1977, *135*
7-18 Recreational use of the National Forests, by activity, 1977, *136*

Rangeland

7-19 Rangeland, *138*
7-20 Ownership of rangeland, 1977, *139*
7-21 Rangeland, by ecosystem, 1976, *140*
7-22 Quality of rangeland, by ecosystem, 1976, *142*
7-23 Productivity of rangeland, by ecosystem, 1976, *144*

Chapter 8
Wildlife

8-1 Distribution of vertebrate species and major subspecies, by region, 1970s, *148*

Mammals

8-2 Selected large mammal populations on Bureau of Land Management lands, 1961–1975, *150*
8-3 Selected large mammal populations in National Forests and National Grasslands, 1960–1978, *151*
8-4 Animals removed or killed by Federal predator control activities, 1937–1978, *152*

Birds

8-5 Bird species observed, 1968–1977, *152*
8-6 Selected bird species populations, 1966–1977, *154*
8-7 Most frequently observed breeding bird species, 1977, *155*
8-8 Distribution of North American breeding and wintering ducks, 1970s, *156*
8-9 Duck breeding populations in North America, 1955–1979, *157*
8-10 Duck harvest, by flyway, 1952–1978, *158*
8-11 Brown pelican populations and toxic residues in eggs, 1969–1976, *159*

Fish

8-12 Distribution of fish species and major subspecies, by type of environment and region, 1970s, *160*
8-13 U.S. and foreign fish catch in U.S. waters, 1950–1979, *161*
8-14 U.S. and foreign catch of selected fish species in U.S. waters, 1950–1979, *162*
8-15 Estuarine habitat lost to dredging and filling, 1950–1969, *164*
8-16 Fish kills caused by pollution, 1961–1976, *165*

Extinct, threatened, and endangered species

8-17 Extinct vertebrate species and subspecies, 1760–1979, *166*
8-18 Threatened and endangered animal species in the United States, December 1979, *167*
8-19 Population of selected threatened and endangered species, 1941–1979, *168*
8-20 Condition of selected threatened and endangered species, *169*

Chapter 9
Energy

Consumption and production

9-1 Energy consumption, by fuel type, 1850–1978, *176*
9-2 Energy consumption, by fuel type, 1950–1978, *177*
9-3 Net trade in energy resources, 1950–1978, *178*
9-4 Energy production, by fuel type, 1850–1978, *178*
9-5 Energy production, by fuel type, 1950–1978, *180*
9-6 Energy flow in the U.S. economy, 1975, *181*
9-7 Energy consumption, by sector, 1950–1978, *182*
9-8 Energy consumption, by end use, 1950–1978, *183*
9-9 Residential heating, by fuel type, 1940–1975, *184*
9-10 Residential heating, by fuel type and by county, 1970, *184*
9-11 Per capita energy consumption and gross domestic product for four nations, 1961–1977, *186*
9-12 Energy consumed by sector for nine nations, 1972, *188*

Fuel cycles

9-13 Energy supply systems for fossil fuels, *189*
9-14 Coal fields, 1970s, *190*
9-15 Coal production, 1900–1978, *191*
9-16 Land disturbed and reclaimed by the coal mining industry, 1930–1978, *192*
9-17 Streams affected by acid mine drainage, 1970s, *192*
9-18 Coal mine deaths from accidents, 1906–1978, *193*
9-19 Natural gas and petroleum fields, 1970s, *194*
9-20 Natural gas and oil production, 1950–1978, *195*
9-21 Liquified natural gas facilities, 1980, *196*
9-22 The nuclear fuel cycle, *197*
9-23 Nuclear reactors built, being built, or planned, September 1973–December 1979, *198*
9-24 Nuclear reactors, December 1979, *198*
9-25 Nuclear power generation, 1957–1979, *200*
9-26 Low-level radioactive wastes disposed of, 1962–1979, *201*
9-27 Radioactive waste disposal sites, 1979, *202*
9-28 Production of hydropower, 1950–1978, *203*
9-29 Geothermal resources, 1970s, *204*
9-30 Production of electricity from geothermal resources, 1970–1978, *205*
9-31 Solar collectors manufactured, 1974–1979, *206*

Chapter 10
Water resources

Abundance and distribution

10-1 The hydrologic cycle, *210*
10-2 Water resource regions, 1975, *211*
10-3 Average annual precipitation, 1931–1960, *212*
10-4 Available ground water, 1975, *213*
10-5 Ground water withdrawals, 1975, *214*
10-6 Ground water overdraft, 1975, *215*
10-7 Average streamflow of large rivers, 1941–1970, *216*
10-8 Inadequate surface water supply for instream use, 1975, *217*
10-9 Flooding problems, 1975, *218*

Use

10-10 Water use, 1900–1975, *219*
10-11 Water withdrawal, by use, 1950–1975, *220*
10-12 Water consumption, by use, 1960–1975, *221*
10-13 Water withdrawal and consumption in the Pacific Northwest and California regions, 1960–1975, *222*
10-14 Water withdrawal and consumption in the Great Basin, Upper Colorado, and Lower Colorado regions, 1960–1975, *224*
10-15 Water withdrawal and consumption in the Missouri, Arkansas-White-Red, Rio Grande, and Texas-Gulf regions, 1960–1975, *226*
10-16 Water withdrawal and consumption in the Souris-Red-Rainy, Upper Mississippi, and Lower Mississippi regions, 1960–1975, *228*
10-17 Water withdrawal and consumption in the Great Lakes, Ohio, and Tennessee regions, 1960–1975, *230*
10-18 Water withdrawal and consumption in the New England, Mid-Atlantic, and South Atlantic-Gulf regions, 1960–1975, *232*
10-19 Water withdrawal and consumption in Alaska, Hawaii, and Caribbean regions, 1960–1975, *234*

Chapter 11
Water quality

11-1 Sources and effects of water pollutants, *238*

Rivers and streams

11-2 Fecal coliform bacteria, average annual violation rates, 1975–1979, *240*
11-3 Fecal coliform bacteria in U.S. waters, 1978, *241*
11-4 Fecal coliform bacteria in major rivers, 1966–1978, *242*
11-5 Dissolved oxygen, average annual violation rates, 1975–1979, *244*
11-6 Dissolved oxygen in U.S. waters, 1978, *245*
11-7 Dissolved oxygen in major rivers, 1966–1978, *246*
11-8 Total phosphorus, average annual violation rates, 1975–1979, *248*
11-9 Total phosphorus in U.S. waters, 1978, *249*
11-10 Total phosphorus in major rivers, 1966–1978, *250*
11-11 Heavy metals, 1975–1978, *252*
11-12 Phenols in the Upper Ohio River basin, 1968–1976, *254*
11-13 Discharges to water, by pollutant and by point and nonpoint sources, 1977, *255*
11-14 Point source discharges to water, by sector, 1977, *256*
11-15 Population served by municipal wastewater systems, by level of treatment, 1960–1978, *258*

Lakes

11-16 Eutrophication of U.S. lakes, 1975, *262*
11-17 Water quality problem areas of the Great Lakes, 1978, *263*
11-18 Toxic residues in Great Lakes fish, 1969–1976, *264*

Oceans

11-19 Ocean dumping of U.S. wastes by barge, 1951–1978, *266*
11-20 Oil spills in U.S. waters, 1971–1978, *267*
11-21 Toxic residues in coastal mussels and oysters, 1976, *268*

Chapter 12
Air quality

12-1 Criteria and noncriteria air pollutants, *272*
12-2 Pollutant Standards Index values, pollutant levels, and health effects, *274*

Ambient conditions

12-3 Average Pollutant Standards Index for 23 Standard Metropolitan Statistical Areas, 1974–1978, *275*
12-4 Pollutant Standards Index in 24 Standard Metropolitan Statistical Areas, 1973–1978, *276*
12-5 National ambient carbon monoxide concentrations, 1972–1978, *280*
12-6 National ambient ozone concentrations, 1972–1977, *280*
12-7 National ambient sulfur dioxide concentrations, 1972–1977, *281*
12-8 National ambient total suspended particulate concentrations, 1972–1977, *281*
12-9 Ambient nitrogen dioxide concentrations, selected areas, 1972–1977, *282*
12-10 Ambient trace metal concentrations in 92 urban areas, 1965–1974, *283*
12-11 Acid precipitation in the eastern United States, 1955–1976, *284*

Emissions

12-12 Carbon monoxide emissions, 1970–1977, *285*
12-13 Hydrocarbon emissions, 1970–1977, *286*
12-14 Nitrogen oxide emissions, 1970–1977, *287*
12-15 Nitrogen oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977, *287*
12-16 Sulfur oxide emissions, 1970–1977, *288*
12-17 Sulfur oxide emissions from stationary fuel combustion sources, by fuel type, 1970–1977, *288*
12-18 Total suspended particulate emissions, 1970–1977, *289*
12-19 Total suspended particulate emissions from industrial sources, 1970–1977, *289*
12-20 Compliance status of major stationary air pollution sources, 1975–1979, *290*
12-21 Compliance status of major stationary air pollution sources, by industry, 1979, *291*

Chapter 13
Biosphere

Population

13-1 World population, by region, 1800–1979, *296*
13-2 World population growth rates, by region, 1950–1979, *298*
13-3 Population density, 1975, *298*
13-4 Population in urban and rural areas, by size of area, 1920–1975, *300*
13-5 Ten largest cities in the world, 1975, *301*
13-6 Population by region, 1950–1979, with projections to 2000, *302*

Land

13-7 Major ecosystems of the world, 1970s, *304*
13-8 Area and productivity of ecosystems, 1970s, *306*
13-9 Tropical moist forests, 1970s, *306*
13-10 Tropical moist forests, by region and country, 1945–1978, *308*
13-11 Lands vulnerable to desertification, 1970s, *310*
13-12 World arable land, 1951–1975, *312*
13-13 Arable and potentially arable land, by region, 1970s, *313*
13-14 World agricultural production, 1954–1978, *314*
13-15 World agricultural inputs, 1950–1978, *315*

Wildlife

13-16 Extinct species and subspecies of vertebrate animals worldwide, 1600s–1900s, *318*
13-17 Extinction of species, by region, 1980–2000, *319*
13-18 Whale exploitation by species, pre-hunting through the 1970s, *320*
13-19 Population of selected endangered and threatened species, 1947–1979, *322*

Oceans

13-20 World commercial fish catch, 1950–1978, *325*
13-21 Areas of marine pollution, 1970s, *326*
13-22 World oil spills from tankers, 1973–1979, *328*

Atmosphere

13-23 Chlorofluoromethane production, 1967–1977, *331*
13-24 Carbon dioxide concentrations in air, 1958–1979, *332*

Abbreviations

bgd	billion gallons per day
BLM	U.S. Bureau of Land Management (DOI)
BOD_5	5-day biochemical oxygen demand
BOM	U.S. Bureau of Mines (DOI)
Btu	British thermal unit
CEQ	Council on Environmental Quality
CFMs	chlorofluoromethanes
CNS	central nervous system
CO	carbon monoxide
CO_2	carbon dioxide
COE	U.S. Army Corps of Engineers
dB	decibel
DDT	1,1,1-Trichloro-2,2-di-(4-chlorophenyl)ethane
DHEW	U.S. Department of Health Education, and Welfare [now HHS]
DO	dissolved oxygen
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ERS	Economic Research Service (USDA) [now ESCS]
ESCS	Economics, Statistics, and Cooperatives Service (USDA) [formerly ERS]
FAA	Federal Aviation Administration (DOT)
FDA	Food and Drug Administration (HHS)
FAO	Food and Agriculture Organization (UN)
FC	fecal coliform bacteria
FHWA	Federal Highway Administration (DOT)
FS	U.S. Forest Service (USDA)
FWS	U.S. Fish and Wildlife Service (DOI)
GDP	gross domestic product
GNP	gross national product
HC	hydrocarbons
HCRS	Heritage Conservation and Recreation Service (DOI)
HHS	U.S. Department of Health and Human Services [formerly DHEW]
HUD	U.S. Department of Housing and Urban Development
ITC	U.S. International Trade Commision
IUCN	International Union for the Conservation of Nature and Natural Resources
kcal	kilocalories
LNG	liquefied natural gas
μg	microgram
$\mu g/l$	microgram per liter
$\mu g/m^3$	microgram per cubic meter
mg	milligram
mg/l	milligram per liter
mg/m^3	milligram per cubic meter
ml	milliliter
mrem	millirem
NAAQS	National Ambient Air Quality Standard
NADB	National Aerometric Data Bank (EPA)
NAS	National Academy of Sciences
NASN	National Air Surveillance Network (EPA)
NASQAN	National Stream Quality Accounting Network (USGS)
NEDB	National Emissions Data Bank (EPA)
NEF	noise exposure forecast
NEPA	National Environmental Policy Act
NGL	natural gas liquids
NIH	National Institutes of Health (HHS)
NMFS	National Marine Fisheries Service (NOAA)
NO_x	nitrogen oxides
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration (DOC)
NPS	National Park Service (DOI)
NRC	U.S. Nuclear Regulatory Commission
NSF	National Science Foundation
NTIS	National Technical Information Service
OECD	Organization for Economic Cooperation and Development
OMB	Office of Management and Budget
O_3	ozone
O_x	oxidants
PCB	polychlorinated biphenyl
PIRS	Pollution Incident Reporting System (U.S. Coast Guard)
PSI	Pollutant Standards Index [for air]
ppb	parts per billion
ppm	parts per million
quad	quadrillion British thermal units
RCC	Resource Conservation Committee (EPA)
rad	radiation absorbed dose
rem	roentgen equivalent man [a unit of radiation dose equivalent]
SCS	Soil Conservation Service (USDA)
SMSA	Standard Metropolitan Statistical Area
SAROAD	Storage and Retrieval of Aerometric Data (EPA)
SO_x	sulfur oxides
SO_2	sulfur dioxide
STORET	Storage and Retrieval [of water data] (EPA)
2,4-D	(2,4-Dichlorophenoxy) acetic acid + esters
TSP	total suspended particulates
UN	United Nations
UNEP	U.N. Environment Program
UNESCO	U.N. Educational, Scientific, and Cultural Organization
UPGRADE	User Prompted Graphic Data Evaluation system (CEQ)
USDA	U.S. Department of Agriculture
USGPO	U.S. Government Printing Office
USGS	U.S. Geological Survey (DOI)
WRC	U.S. Water Resources Council

Maps have been drawn at the following approximate scales: full page width, 1:22 million (see 1-3, p. 4 for example); three-quarter page, 1:31 million (see 1-1, p. 2); half page, 1:44 million (see 5-7, p. 85); and one-quarter page width, 1:80 million (see 7-11, p. 129).

Conversions

English to metric

Weight (or mass)

Avoirdupois (avdp)—for weighing ordinary commodities
Troy—for weighing precious metals, jewels, etc.

Grain (gr)(avdp)
= 0.065 gram (g)

Ounce (oz)(avdp) *or* 437.5 gr (avdp) *or* 16 drams (dr)(avdp)
= 28.350 grams (g)

Pound (lb)(avdp) *or* 7,000 gr (avdp) *or* 16 oz (avdp)
= 0.454 kilogram (kg)

Hundredweight (cwt)(avdp) *or* 100 lb (avdp)
= 45.359 kilograms (kg)

Ton, short (avdp) *or* 2,000 lb (avdp)
= 0.907 metric ton

Ton, long (avdp) *or* 2,240 lb (avdp)
= 1.016 metric tons

Ounce (oz)(troy) *or* 480 gr (troy)
= 31.104 grams (g)

Pound (lb)(troy) *or* 5,760 gr (troy) *or* 12 ounces (oz)
= 0.373 kilogram (kg)

Length and area

Inch (in)
= 25.4 millimeters (mm)

Foot (ft) *or* 12 in
= 0.305 meter (m)

Yard (yd) *or* 36 in *or* 3 ft
= 0.914 meter (m)

Mile (mi) *or* 5,280 ft
= 1.609 kilometers (km)

Square inch (in^2)
= 6.452 square centimeters (cm^2)

Square foot (ft^2) *or* 144 in^2
= 0.093 square meter (m^2)

Square yard (yd^2) *or* 1,296 in^2 *or* 9 ft^2
= 0.836 square meter (m^2)

Acre *or* 43,560 ft^2
= 0.405 hectare (ha)

Square mile (mi^2) *or* 640 acres
= 2.59 square kilometers (km^2)

Volume (or capacity)

Liquid

Fluid ounce (fl oz)
= 29.573 milliliters (ml)

Pint (pt) *or* 16 fl oz
= 0.473 liter (l)

Quart (qt) *or* 32 fl oz *or* 2 pt
= 0.946 liter (l)

Gallon (gal) *or* 8 pt *or* 4 qt
= 3.785 liters (l)

Dry

Pint (pt)
= 0.551 cubic decimeter (dm^3)

Quart (qt) *or* 2 pt
= 1.101 cubic decimeters (dm^3)

Peck (pk) *or* 8 qt
= 8.810 cubic decimeters (dm^3)

Bushel (bu) *or* 32 qt
= 35.238 cubic decimeters (dm^3)

Metric to English

Weight (or mass)

Avoirdupois (avdp)—for weighing ordinary commodities
Troy—for weighing precious metals, jewels, etc.

Microgram (µg)
= 0.000001 g

Milligram (mg)
= 0.001 g

Gram (g)
= 0.035 oz (avdp)
= 0.032 oz (troy)

Dekagram (dag) *or* 10 g
= 0.353 oz (avdp)
= 0.322 oz (troy)

Hectogram (hg) *or* 100 g
= 3.527 oz (avdp)
= 3.215 oz (troy)

Kilogram (kg) *or* 1,000 g
= 2.205 lb (avdp)
= 2.679 lb (troy)

Metric ton *or* 1,000 kg
= 1.102 short tons
= 0.984 long ton

Length and area

Millimeter (mm) *or* 0.001 meter (m)
= 0.039 inch (in)

Centimeter (cm) *or* 0.01 meter (m)
= 0.394 inch (in)

Decimeter (dm) *or* 0.1 meter (m)
= 3.937 inches (in)

Meter (m)
= 3.281 feet (ft)

Kilometer (km) *or* 1,000 meters (m)
= 0.621 mile (mi)

Square millimeter (mm^2) *or* 0.000001 square meter (m^2)
= 0.002 square inch (in^2)

Square centimeter (cm^2) *or* 0.0001 square meter (m^2)
= 0.155 square inch (in^2)

Square decimeter (dm^2) *or* 0.01 square meter (m^2)
= 15.5 square inches (in^2)

Square meter (m^2)
= 10.764 square feet (ft^2)

Hectare (ha) *or* 10,000 square meters (m^2)
= 2.471 acres

Square kilometer (km^2) *or* 1,000,000 square meters (m^2)
= 0.386 square mile (mi^2)

Volume (or capacity)

Milliliter (ml) *or* 0.001 liter (l)
= 0.034 fl oz (liquid)
= 0.002 pt (dry)

Liter (l)
= 1.057 qt (liquid)
= 0.908 qt (dry)

Hectoliter (hl) *or* 100 liters (l)
= 26.418 gal (liquid)
= 2.838 bu (dry)

Units of energy

British thermal unit (Btu)
= 1,055 Joules
= 0.252 kcal

Calorie
= 4.184 Joules

Foot-pound (ft-lb)
= 1.356 Joules
= 0.000324 kcal

Horsepower hour (hp-h)
= 2,684,500 Joules
= 641 kcal
= 2,544 Btu

Joule (J)
= 0.00024 kcal
= 0.0009478 Btu

Kilocalorie (kcal)
= 4,184 Joules
= 1.163 watt-hours
= 3.968 Btu

Kilowatt-hour (kWh)
= 3,600,000 Joules
= 860 kcal
= 3,413 Btu
= 1,000 watt-hours

Quad
= 1 quadrillion Btu

Watt-hour
= 3,600 Joules
= 0.86 kcal
= 3.413 Btu

For more information on conversion, call or write the Metric Information Office, U.S. Metric Board, 1600 Wilson Boulevard, 4th floor, Arlington, VA 22209 (703-235-2820).

Index

- acid rain, 284
- acrylonitrile
  - production, 100
  - uses and effects, 90
- Africa, population, 297, 298, 302
- African elephants
  - population, 322
- agriculture (*see* cropland)
- air quality, 271–293
  - acid rain, 284
  - ambient conditions, 275–284
  - carbon monoxide, 272, 274, 280, 285
  - compliance, 290–291
  - emissions, 285–291
  - hydrocarbons, 272, 286
  - in Standard Metropolitan Statistical Areas, 275–279
  - lead, 273, 283, 292 (tech. note 12-3)
  - metals, 273, 283
  - nitrogen dioxide, 273, 274, 282
  - nitrogen oxide, 287
  - ozone, 272, 274, 280
  - pollutants, sources and effects, 272–273
  - respirable particulates, 273
  - standards, 272–274
  - sulfur dioxide, 272, 274, 281
  - sulfur oxide, 288
  - total suspended particulates, 273, 274, 281, 289
- aircraft, 62, 65, 68
- airports
  - noise, 72
- airways, 62, 65, 67
- Alabama River
  - water quality, 243, 247, 251
- alachlor
  - use by farmers, 94
- aldrin
  - residues in humans, 98
  - residues in water, 96
  - residues in wildlife, 97
  - use by farmers, 95
  - uses and effects, 90
  - *see also* dieldrin
- aluminum
  - consumption, 78, 80, 82
  - recycled, 87
- ambient conditions
  - air quality, 275–284
  - water quality, 240–254
- amphibians, 148–149, 167, 170–171
- appliances in homes, 55
- arsenic
  - ambient concentrations in water, 252
  - cancer associated with, 108
  - criteria, 260 *(tech. note 11-2)*
  - primary demand, 106
  - uses and effects, 91
- asbestos
  - cancer associated with, 104
  - flow in the environment, 101
  - primary demand, 100
  - uses and effects, 90
  - sources and effects, 273
- Asia, 297, 298, 302
- atmosphere
  - global issues, 330–332
- atrazine
  - use by farmers, 94
- automobile, 62–65, 67
  - emissions, 70
  - energy intensity, 68
  - energy used, 67
  - fuel economy, 69
  - noise, 71
  - number of vehicles, 62
  - passenger travel, 63, 65
  - standards, 69, 70
  - transportation to work, 64

- bald eagle, 168, 170
- Bengal tiger
  - population, 322
- benzene
  - production, 100
  - uses and effects, 90
- beryllium
  - sources and effects, 273
- bicycles, 62
- biosphere, 295–333
  - atmosphere, 330–333
  - land use, 304–317
  - oceans, 324–329
  - population, 296–303
  - wildlife, 318–323
- birds, 152–159, 166–170
  - population, 154, 157, 159
  - threats to, 158, 159
  - *see also* ducks
- Black rhinoceros
  - population, 322
- boats, 62, 71
- Breeding Bird Survey, 153, 172 *(tech. note 8-5)*
- Brown pelicans, 159, 169
- Bureau of Land Management lands, 127, 139, 150
- buses, 62, 63, 67, 68, 71

- cadmium
  - ambient concentrations in air, 283
  - ambient concentrations in water, 253
  - cancer associated with, 108
  - criteria for water, 260 *(tech. note 11-2)*
  - primary demand, 106
  - uses and effects, 91
- California condor, 168, 169
- Canada
  - energy, 188
- camping, 34, 136
- cancer associated with toxic substances, 103, 104, 108, 114
- carbofuran
  - use by farmers, 95
- carbon dioxide
  - ambient concentrations in air, 332
- carbon monoxide
  - ambient concentrations in air, 280
  - emissions, 70, 285
  - standards, 70, 272
- carpools, 64
- central cities, 8, 10, 48, 50, 56, 64
- cesium–137
  - effects, 91
  - residues in milk, 112
- chemicals
  - cancer associated with, 103, 104, 108, 114
  - flow in the environment, 101, 107
  - production, 92, 93, 100, 106
  - residues, 96, 97, 98, 102, 112
  - use, 90–91, 94, 95
  - *see also* toxic substances, *specific chemical*
- chlordane
  - residues in water, 96
- chlorofluoromethane
  - production, 331
- chromium
  - primary demand, 106
- climate, 3, 13 *(tech. note 1-2)*
- CO (*see* carbon monoxide)
- coal
  - acid mine drainage, 192
  - consumption, 78, 80, 82, 176–177
  - deaths from mining, 193
  - fuel cycles, 189
  - heating, 184–185
  - impacts, 192, 193
  - location of fields, 190
  - net trade, 178
  - production, 178–180, 191
  - reclamation of land, 192
  - surface land used, 192
  - surface mining, 191, 193
  - underground mining, 191, 193
- coasts
  - modification from dredging and filling, 164
  - population density, 7
  - protection, 20
- Colorado River
  - water use, 224–225
- Columbia River
  - water quality, 242, 246, 250
- compliance
  - industrial emissions, 290–291
- critical areas, 15–44
  - historic places, 36–37
  - parks, 28–35
  - risk zones, 38–44
  - wetlands, 16–21
  - wild areas, 22–27
- cropland, 49, 118–125
  - agricultural inputs, United States, 122–123
  - agricultural inputs, world, 315
  - agricultural production, 121, 314
  - arable land, world 312–313
  - erosion, 124
  - irrigation, 123, 220, 221, 315
  - location, 118
  - pesticides used on, 94, 95
  - prime farmland, 119, 120
  - use, 119

- DDT
  - residues in birds, 97, 159
  - residues in fish, 97, 264
  - residues in humans, 98
  - residues in mussels and oysters, 268
  - residues in water, 96
  - use by farmers, 95
  - uses and effects, 90
- desertification, 310–311
- Delaware River
  - water quality, 243, 247, 251
- dieldrin
  - residues in birds, 97, 159
  - residues in fish, 97, 264
  - *see also* aldrin
- discharges to water, 255–257
- dissolved oxygen
  - ambient concentration in rivers, 244–247
  - criteria for water quality, 244, 260 *(tech. note 11-2)*
  - sources and effects, 239
- ducks
  - distribution, 156
  - harvest, 158
  - population, 157
- dumps, 84, 88 *(tech. note 5-5)*

- earthquakes
  - lives lost, 42
  - location, 41
  - property damage, 43
- electricity
  - appliances in homes, 55
  - energy consumed, 181, 182
  - heating, 184–185
  - production, 200, 205
  - water used by electric utilities, 220–221
- emissions
  - auto, 70
  - pollutants in air, 285–291
- energy, 175–208
  - consumption, 176, 177, 181–183, 186–188
  - environmental impacts, 192–193, 201
  - farm use, 123
  - fuel cycles, 181, 189, 197
  - industrial uses, 182, 183, 188
  - international comparisons, 186–188
  - location of resources, 190, 194, 204
  - losses, 181, 188
  - net trade, 178
  - pipelines, 62, 65–67
  - production, 178–181, 191, 195, 200, 203, 205
  - renewable sources, 206

(energy, *cont.*)
  residential and commercial use, 182–185, 188
  residential heating, 184–185
  transportation use, 67, 68, 182, 183, 188
  see also coal, electricity, geothermal resources, hydropower, natural gas, nuclear power, oil, pipelines, solar energy
erosion, 124
estuary
  modification from dredging and filling, 164
ethyl parathion
  use by farmers, 95
  uses and effects, 90
eutrophication, 248, 262

farms
  energy use, 123
  see also cropland
fecal coliform bacteria, 239–243
  ambient concentrations in rivers, 240–243
  criteria for water quality, 240, 260 *(tech. note 11-2)*
  sources and effects, 239
fertilizer
  use, United States, 122
  use, world, 315
fires, 134
fish, 160–165, 171
  catch, United States, 161–163
  catch, world, 325
  killed by pollution, 165
  toxic residues in, 97, 102, 264
floods
  area affected, 39
  lives lost, 42
  location, 218
  population affected, 39
  property damage, 43
forest, 49, 126–137
  area, 128–129
  condition, 134
  defoliation, 134
  ecosystems, 128
  growth, 130–132
  harvest, 130–133
  location, 126
  National, 127, 131, 132, 135, 136, 151
  ownership, 127, 131, 132
  recreational use, 135, 136
  reforestation, 134
  tropical moist forests, world, 306–309
  wildfire, 134
France
  energy, 188
fuelwood
  consumption, 176
  harvest, 133
  production, 178
fungicide
  production, 92

gas (*see* natural gas)
geothermal resources
  consumption, 176–177
  electricity produced from, 205
  location of resources, 204
  production, 178–180
glass
  recycled, 87
  solid waste disposed, 86
Golden lion marmoset
  population, 322
Great Lakes
  toxic residues in fish, 264
  water quality problems, 263
gross domestic product, 186–187
ground water (*see* water resources)

hazardous waste, 85, 88 *(tech. note 5-6)*
HC (*see* hydrocarbons)
heptachlor epoxide
  residues in humans, 98
herbicide
  production, 92
  use by farmers, 94
highways, 67
historic places, 36–37
housing
  characteristics, 52, 53
  condition, 54
  electric appliances, 55
  energy consumed, 181–183
  facilities, 52, 53
  fuel used for heating, 184–185
  multifamily, 50, 53
  public opinion, 56
  single family, 50, 52
  size, 52, 53
  structure, 52, 53
  units, 50, 51
Hudson River
  water quality, 243, 247, 251
human settlements, 45–60
  housing conditions, 52–56
  housing units, 50–51
  neighborhood conditions, 56–59
  settlement patterns, 45–49
  see also housing, neighborhood
hurricanes
  lives lost, 42
  location, 40
  property damage, 43
hydrocarbons
  emissions from all sources, 286
  emissions from automobiles, 70
  sources and effects, 272
hydropower
  consumption, 176–177
  production, 178–181, 203

industrial chemicals, 100–105
  cancer associated with, 103, 104
  flow in the environment, 101
  production, 100
  residues in humans, 102
  residues in wildlife, 102
industry
  compliance with air pollution standards, 288, 289
  energy consumed by, 181–183
  hazardous wastes, 85
  solid wastes, 84
insecticides
  production, 92, 93
  use by farmers, 95
international energy consumption, 186–188
irrigation
  area covered, world, 315
  water use, United States, 123, 220–221
Italy
  energy, 188

Japan
  energy, 188

Kemp's ridley turtle
  population, 171, 322
Key deer, 168, 169
krypton-85
  residues in air, 112
  sources and effects, 91

landfills, 84, 88 *(tech. note 5-5)*
land use, 117–146
  in Standard Metropolitan Statistical Areas, 49
  landfills, 84, 88 *(tech. note 5-5)*
  physical characteristics, United States, 2
  world issues, 304–317
  see also biosphere, critical areas, cropland, energy, forests, rangeland, transportation
lead
  ambient concentrations in air, 283
  ambient concentrations in water, 253
  cancer associated with, 108
  characteristics in air, 273
  criteria for water quality, 260 *(tech note 11 2)*
  primary demand, 106
  residues in mussels and oysters, 269
  standards for air, 273
  uses and effects, 91
lumber
  consumption, 79, 81, 83

malathion
  residues in water, 96
mammals, 148–152, 166–169
  population, 150–151
  threats to, 152
material use, 75–84
  consumption, 78–83
  flow of materials, products, wastes, 76–77
Mauritius kestrel
  population, 322
mercury
  ambient concentrations in water, 252
  criteria for water, 260 *(tech. note 11-2)*
  flow in the environment, 107
  primary demand, 106–107
  residues in fish, 264
  uses and effects, 91
metals, 106–109
  ambient concentrations in air, 283
  ambient concentrations in water, 252–253
  cancer associated with, 108
  consumption, 78, 80, 82
  discharges to water, 255, 257
  flow in the environment, 107
  primary demand, 106–107
  recycled, 87
  residues in fish, 264
  residues in mussels and oysters, 269
  solid waste disposed, 86
  sources and effects, 91, 239, 273
  see also specific metal
methyl parathion
  use by farmers, 95
  uses and effects, 90
minerals
  consumption, 78 80, 82
Mississippi River
  water quality, 243, 247, 251
  water use, 228–229
Missouri River
  water quality, 243, 247, 251
  water use, 226–227
mobile homes, 44 *(tech. note 2-22)*, 50
mopeds, 63
motorcycles, 62, 63, 71
motor vehicles (*see* transportation, *specific mode*)
Mountain gorilla
  population, 322
municipal sewer facilities
  discharges to water, 256–257
  population served by, 258–259
Mussel Watch Program, 268, 269 *(tech. note 11-21)*

NASQAN, 240, 241, 244, 245, 248, 249, 260 *(tech. note 11-2)*
National Ambient Air Quality Standards, 272–274
National Forests, 127, 131, 132, 135, 136, 151
National Parks, 28–35
National Pesticide Monitoring Program, 97, 99 *(tech. note 6-7)*

National Register of Historic Places, 36–37
National Wild and Scenic Rivers System, 25, 26
National Wilderness Preservation System, 22–24
natural gas
  consumption, 79, 81, 83, 176–177
  fuel cycle, 189
  heating, 184–185
  location of fields, 194
  location of LNG facilities, 196
  net trade, 178
  production, 178–181, 195
neighborhood
  deficiencies, 58, 59
  public opinion, 56
  services, 57
Netherlands
  energy, 187, 188
nickel
  ambient concentrations in air, 283
  primary demand, 106–107
nitrogen dioxide
  ambient concentrations, 282
  emissions, 70, 287
  sources and effects, 273
  standards, 273–274
noise
  airports, 72
  motor vehicles, 71
  public opinion, 58, 59
nonmetropolitan population, 8, 10, 48, 50, 56, 64
nuclear power
  consumption, 176–177
  electricity produced, 200
  fuel cycle, 197
  production, 178–181
  radiation, 110–115
  reactors, 198–199
  waste disposal sites, 202
  waste disposed of, 201

oceans
  areas of pollution, 326–327
  dumping, United States, 266
  fish catch, world, 325
  global issues, 324–329
  oil spills, world, 328
Ohio River
  dissolved oxygen in, 247
  fecal coliform bacteria in, 243
  phenols in, 254
  phosphorus in, 251
  water use, 230–231
oil
  consumption, 79, 81, 83, 176–177
  heating, 184–185
  location of fields, 194
  net trade, 178
  pollution in oceans, 326–327
  production, 178, 181, 195
  spills, United States, 207
  spills, world, 327, 328
oxidants, 272
  see also ozone
oxychlordane
  residues in humans, 98
ozone
  ambient concentrations, 280
  sources and effects, 272
  standards, 272, 274

paper
  disposed as waste, 86
  recycled, 87
parathion
  use by farmers, 95
  uses and effects, 90
parks, 28–35
  acreage, 31
  location, 29
  National, 28–35
  number, 30
  representation, 32
  State, 31, 33
  visits, 33–35
pasture land, 49, 119
PCBs
  production, 100–101
  residues in birds, 102, 159
  residues in fish, 102, 264
  residues in mussels and oysters, 268
  uses and effects, 90
pesticides, 90, 92–99
  production, 92–93
  residues in fish, 97, 264
  residues in humans, 98
  residues in mussels and oysters, 268
  residues in water, 96, 239
  residues in wildlife, 97
  use by farmers, 94, 95, 123
  uses and effects, 90
petroleum (*see* oil)
phenols, 254
phosphorus, 239, 248–251
  ambient concentrations in rivers, 248–251
  criteria for water quality, 248, 260 *(tech. note 11-2)*
  discharges to water, 255, 257
  sources and effects, 239
phthalates
  production, 100
  uses and effects, 90
pipelines, 62, 65–67
plastics, 78, 80, 82
pollutants
  air, 272–273
  toxic substances, 90–91
  water, 239
Pollutant Standards Index, 274–279
pollution
  fish kills, 165
  oceans, 326–329
  see also air quality, water quality
polychlorinated biphenyls (*see* PCBs)
polyvinyl chloride
  cancer associated with, 103
population, 1–14
  cancer rates, 103, 104, 108, 114
  central cities, 8, 10, 48, 50, 56, 64
  coastal, 7
  density, 7, 48
  distribution, 4, 6–13
  exposure to radiation, 110–111, 113
  flooding, affected by, 39
  growth, 5, 8–13
  growth rates, 5, 6
  metropolitan, 8–10, 48, 50, 56, 64
  migration, 10
  nonmetropolitan, 8, 10, 11, 48, 50, 56, 64
  projections, 5, 12
  region, 6
  sewer facilities, 258–259
  Standard Metropolitan Statistical Areas, 8–10, 13 *(tech. note 1-10)*, 46–50, 56, 64
  suburbs, 8, 10, 48, 50, 56, 64
  total, 4, 5
  toxic residues in, 98, 102
  United States, 1–14
  urban regions, 12
  wildlife, 150, 151, 154, 157, 159, 168, 169–171, 320–323
  world, 296–303
Potomac River
  water quality, 243, 247, 251
prime farmland, 119, 120
PSI (*see* Pollutant Standards Index)
public opinion
  housing, 56
  neighborhood, 59
  noise, 58–59
public transportation, 64
  public opinion, 57

radiation, 91, 110–116
  cancer associated with, 114
  exposure, 110–111, 113
  residues in milk and air, 112
  sources and effects, 91, 239, 273
  waste disposal sites, 202
  wastes disposed of, 201
railroads, 62, 63, 65, 67, 68, 71
rangeland, 138–145
  area, 140–141
  ecosystems, 140–144
  location, 138
  ownership, 139
  productivity, 144
  quality, 142–143
recreation
  camping, 34
  National Forests, 135–136
recreational vehicles, 34, 63, 71
recycling, 77, 86, 87 *(tech. note 5-1)*
Red River
  water quality, 242, 246, 250
  water use, 226–227
reptiles, 148–149, 167, 170–171
resource recovery, 77, 87 *(tech. note 5-1)*
Rio Grande
  water quality, 242, 246, 250
  water use, 226–227
risk zones, 38–44
  earthquakes, 41–43
  floods, 39, 42, 43
  hurricanes, 40, 42, 43
  lives lost, 42
  property damage, 43
  tornadoes, 41–43
roads, 62
rubber
  recycled, 87
SMSA (*see* Standard Metropolitan Statistical Area)
snowmobiles, 63, 71
solar energy
  collectors manufactured, 206
solid waste, 75–77, 84–87
  consumer, 86–87
  industrial, 84–85
  ocean dumping, 266
  radioactive, 201
  see also waste
Standard Metropolitan Statistical Area
  air quality in, 275–279, 292 *(tech. note 12-3)*
  definition, 8, 14 *(tech. note 1-10)*
  density, 48
  growth, 9, 10
  housing in, 50
  land use in, 49
  location, 46–47
  migration, 10
  population, 8, 48
  public opinion, 56
  transportation, 64
standards
  auto emission, 70
  pollutants in air, 272–274
  pollutants in fish, 264
  pollutants in water, 240, 244, 248, 260 *(tech. note 11-2)*
strontium-90
  residues in milk, 112
  sources and effects, 91
suburbs, 8, 10, 48, 50, 56, 64
subways, 62, 71
sulfur dioxide
  ambient concentrations, 281
  sources and effects, 272
  standards, 272, 274
sulfur oxide
  emissions, 288
Susquehanna River
  water quality, 243, 247, 251
Sweden
  energy, 188

Three Mile Island
  radiation exposure, 113
timber (*see* forests)
tornadoes
  lives lost, 42
  location, 41
  property damage, 43

total suspended particulates
  ambient concentrations, 281
  emissions, 289
  sources and effects, 273
  standards, 273, 274
toxaphene
  residues in wildlife, 97
  use by farmers, 95
  uses and effects, 90
toxic substances, 89-116
  cancer associated with, 103, 104, 108, 114-115
  flow in the environment, 101, 107
  industrial chemicals, 100-105
  metals, 106-109
  pesticides, 92-99
  production, 92, 93, 100, 106
  radiation, 110-116
  residues in humans, 98, 102
  residues in mussels and oysters, 268-269
  residues in water, 96
  residues in wildlife, 97, 102, 159, 264
  use by farmers, 94, 95
  uses and effects, 90-91
  see also specific chemical
trifluralin, 94
trains, 62, 63, 65, 67, 68, 71
transportation, 61-74
  commuting, 65
  energy used, 67-68, 181-183
  emissions, 70, 285-289
  freight, 65-66, 68
  impacts on the environment, 67-72
  networks, 62
  noise, 71, 72
  passenger, 63-65, 68
  use of the system, 63-65
  vehicles, 62-63
  see also specific mode
trucks, 62, 65, 67, 68, 71
TSP (*see* total suspended particulates)
2,4-D
  residues in water, 96
  use by farmers, 94
  uses and effects, 90

United Kingdom
  energy, 187, 188
USSR, 297, 298, 302

vinyl chloride
  cancer associated with, 103
  production, 100-101
  sources and effects, 90, 273

waste
  energy lost, 181, 188
  radioactive, 201, 202
  see also solid waste, hazardous waste
water quality, 237-270
  ambient conditions, 240-254, 262
  criteria, 240, 244, 248, 260 *(tech. note 11-2)*
  discharges, 255-257
  dissolved oxygen, 239, 244-247
  eutrophication, 248, 262
  fecal coliform bacteria, 238-243
  Great Lakes, 263
  lakes, 262-264
  metals, 252-253
  municipal sewer facilities, 256-259
  ocean dumping, 266
  oceans, 266-269, 326-327
  oil spills, 267, 327, 328
  phenols, 254
  phosphorus, 239, 248-251
  population with sewer facilities, 258-259
  rivers, 240-259
  toxic residues in fish, 264
  toxic residues in mussels and oysters, 268-269
  toxic residues in water, 96, 252-253
  violation rate definition, 260 *(tech. note 11-2)*
water resources, 209-236
  consumption, 219, 221-235
  distribution, 212-218
  floods, 39, 218
  ground water availability, 213
  ground water overdraft, 215
  ground water withdrawals, 214
  hydrologic cycle, 210
  irrigation, 123, 315
  precipitation, 212
  regional use, 222-235
  stream flow, 216
  surface water, 216-218
  Water Resources Council regions, 211, 236 *(tech. note 10-2)*
  withdrawal, 219, 220, 222-235
  use, 219-235
Water Resources Council, 211, 236 *(tech. note 10-2)*
waterways, 62, 65, 68
West Germany
  energy, 186, 188
wetlands, 16-20
  acreage, 18-19
  location, 17
  lost, 164
  National Wetlands Inventory, 21 *(tech. note 2-1)*
  protection, 20
  use, 19
whales, 320-321
whooping cranes, 168, 170
wild areas, 22-26
  location, 23, 25
  National Wild and Scenic Rivers System, 25, 26
  National Wilderness Preservation System, 22-24
  size, 24, 26
wildfires, 134
wildlife, 147-174, 318-323
  abundance, 147-157, 160, 168-171
  amphibians, 148-149, 167, 170-171
  birds, 152-159, 166-170
  critical habitats, 168
  endangered and threatened species, U.S., 167-171, 173 *(tech. note 8-18)*
  endangered and threatened species, worldwide, 322
  extinct species, U.S., 166, 173 *(tech. note 8-17)*
  extinct species, worldwide, 318-319
  fish, 160-165, 171, 264
  fish catch, U.S., 161-163
  fish catch, world, 325
  mammals, 148-152, 166-169
  populations, 150, 151, 154, 157, 159, 168-171, 320-322
  predator control, 152
  reptiles, 148-149, 167, 170-171
  threats to, 152, 158, 159, 161-166, 169-171
  toxic residues in, 97, 102, 159, 264, 268-269
  United States, 147-174
  whales, 320-321
  world issues, 318-323
wood (*see* energy, forests, fuelwood)
world
  atmosphere, 330-333
  land use, 304-317
  oceans, 324-329
  population, 296-303
  wildlife, 318-323

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